"পাতাল ফেড়ে নামব নীচে, উঠব আবার আকাশ ফুঁড়ে;
বিশ্ব-জগৎ দেখবো আমি আপন হাতের মুঠোয় পুরে।"

— কাজী নজরুল ইসলাম

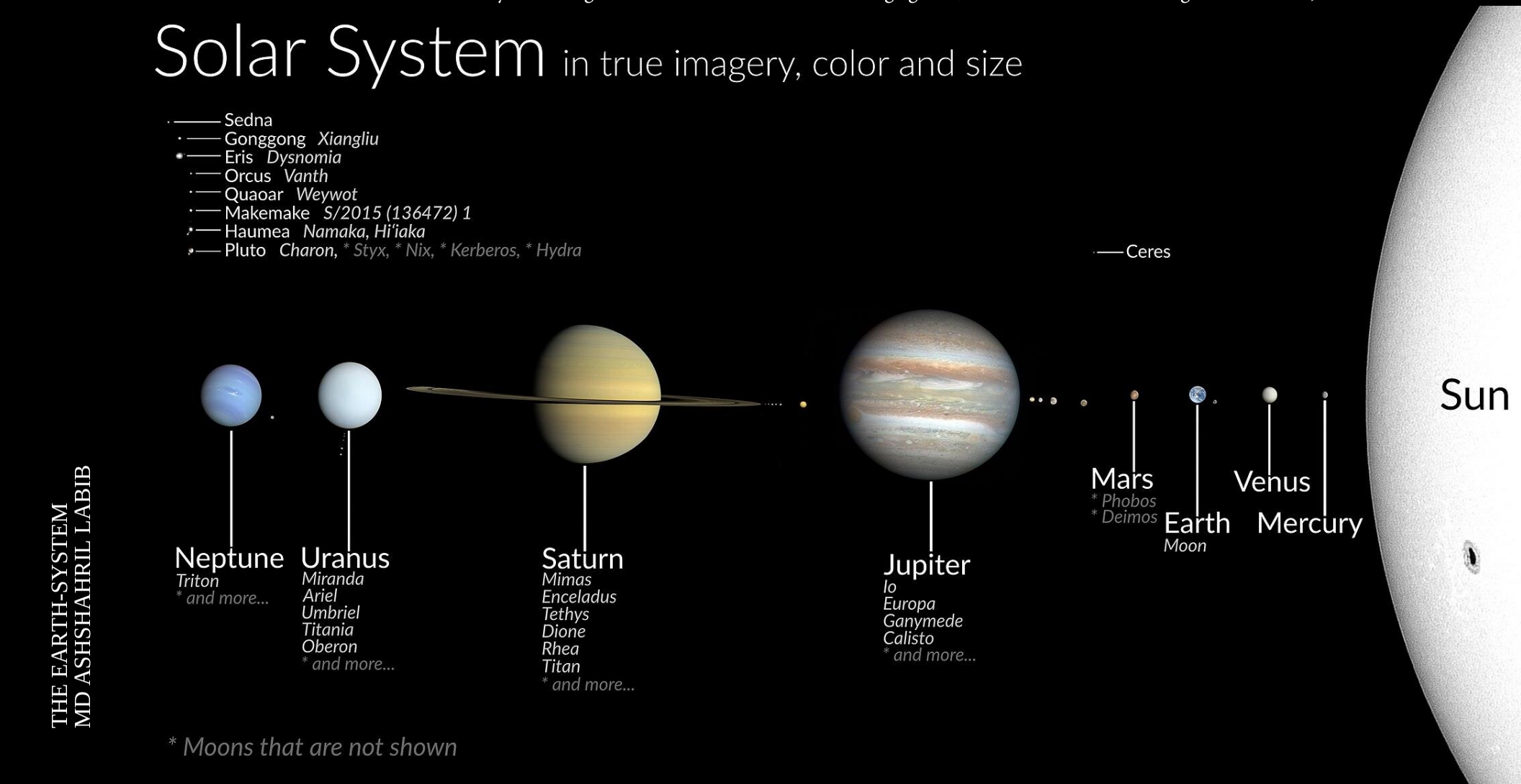
"Have no fear of perfection; you'll never reach it."
– Marie Curie

"If I have seen further , it is by standing on the shoulders of giants." - Sir Isaac Newton

"Imagination is more important than knowledge. For knowledge is limited to all we now know and understand, while imagination embraces the entire world, and all there ever will be to know and understand." -Albert Einstein

"We live on an island surrounded by a sea of ignorance. As our island of knowledge grows, so does the shore of our ignorance." - John Archibald Wheeler

Solar System in true imagery, color and size



* Moons that are not shown

THE EARTH-SYSTEM
MD ASHSHAHRIL LABIB

How unique is our planet? What about our solar system, or our galaxy, the Milky Way? Which was the first planet to be discovered? Why is Pluto not a planet? What does it mean to be a planet? Where did the definition of a planet come from? Who has the authority to define a planet? Do you remember the planet Volcan? What about that? Where does our planet match with the other planets in the solar system? Or our moon with the other moons of the solar system? In this book, we will try to find the answers of these questions. Some small topics of science have been discussed and some covered history has been dug out.

All praise be to Allah, I finally finished it. Let me make it clear at the outset that I am not a physicist, not an astronomer nor an astrophysicist. So this book is not a reference book. However, I have tried to provide the sources of all the information that I have given in this book so that those who read this book can match them and if they wish, they can read the beautiful books and articles that I have given as sources.

We all know the story, but Dr. Khandaker Abdullah Jahangir (rah.) Sir's presentation of this topic impressed me a lot. That is, the barber who used the cut off moles without thinking through, that the doctor couldn't, that story. Abdullah Jahangir (rah.) told the story to explain the difference between Islamic thinkers and Islamic scholars. I have already said that I am not a physicist, or astronomer, nor an astrophysicist, that is, I am like that barber. I can say on my behalf that I have written this book with as much caution as possible. So if anyone find any mistake in this book, please forgive it with your generous heart. And I request you to read this book along with the books that I have used as references.

Wikimedia Foundation helped me most while writing this book. Most of the pictures I have used, except for a few exceptions, are taken from Wiki Commons. I have been able to pay credits of these pictures, but I couldn't give credit to the beautiful articles from Wikipedia that have helped me write this book. Because simply, like my book, Wikipedia articles cannot be used as references. So in this part I would like to express my gratitude to all the members and volunteers of the Wikimedia Foundation, without you this book might not have been possible.

What would this book be like if the world was not like this?

فِيهَا فَأَنبَتْنَا مَاءً السَّمَاءِ مِنَ وَأَنزَلْنَا ۚ دَابَّةٍ كُلِّ مِن فِيهَا وَبَثَّ بِكُمْ تَمِيدَ أَن رَوَاسِيَ الْأَرْضِ فِي وَأَلْقَىٰ ۖ تَرَوْنَهَا عَمَدٍ بِغَيْرِ السَّمَاوَاتِ خَلَقَ كَرِيمٍ زَوْجٍ كُلِّ مِن

He created the heavens without pillars that you see and has cast into the earth firmly set mountains, lest it should shift with you, and dispersed therein from every creature. And We sent down rain from the sky and made grow therein [plants] of every noble kind. (Surah Luqman, verse 10)

Contents:

1. Planetary-Mass Object
2. Planet? Where's her ID?
3. Ashes to Ashes, Dust to Dust
4. Milky Threads
5. Helios and 26-Year-Old Helium
6. Eight Wanderers and One Starry-Eyed
7. Companion Keeper?
8. One and Only Earth-System

Planetary-Mass Object

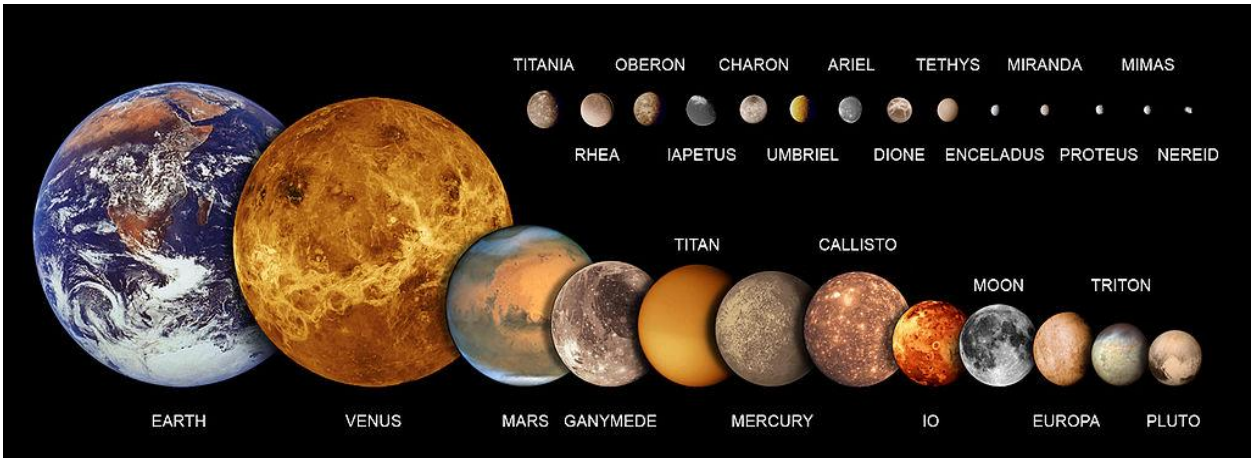


Figure 1: Different celestial objects of the Solar System

Planetary-mass object, abbreviated as **PMO** and sometimes known as **planemo**. According to the geophysical definition of celestial objects, a planetary-mass object is a celestial object that can achieve hydrostatic equilibrium (to be rounded under its own gravity) by its own gravitational force, but cannot cause fusion (a type of nuclear reaction that produces heat and light in stars) like a star. Hydrostatic equilibrium is the state of a fluid, where the fluid is at rest. [1]

The fluid is at rest? But how? Since the Earth is a planet, it is definitely a planetary-mass object. If any fluid (gaseous and liquid substances are called fluids) on any planetary-mass object remains at rest, then there is no question of any rise or fall of water or any other liquid or gas on Earth. But what about the tons of water that are flowing towards the Bay of Bengal every day through the Padma River next to your home? Is the water of Padma not fluid then? And those those ice cubes that fall from the faucets of your bathroom?

There is an atmosphere around our Earth which constantly exerts pressure on the surface of the Earth. Imagine a small piece of land of one square meter on the surface of the Earth. How much weight does the column of air above this small piece of land have? 10.3 tons or 10,332 kg. The largest elephant in the world, the African bush elephant (male), weighs less than that, 5.2-6.9 tons. And our Asian elephants (male) weigh only 3.5-4.6 tons. [2] Imagine you are lying on the beach of St-Martin's Island with your one square meter body and enjoying the shiny weather, there are two full-grown Asian male elephants standing on your smooth, well-built, oily body!

Anyway, this weight of the air column decreases as you go up. Suppose you have fifty goats, each weighing 10 kg and each one meter tall. Now one day you wake up in the morning feeling good, brushing your teeth and enjoying the cold morning air, you go to the goat shed and see that your goats have made a 50-meter-high goat-pillar by standing on each other's backs (don't ask me why or how the goats will do such a thing. The goats are not mine; they are yours).

Seeing this situation, you indulge in anger and decide to sell off all the goats. So, you borrow a weight measuring device from your close-fisted neighbor after a lot of begging.

The goat at the bottom was lifted up on the machine with a lot of spells and tricks. Since the goats were standing on each other's backs, you measured the weight of 50 goats at once as 500 kg. But the buyer you are going to sell the goats to wants guarantee that the weight of each goat is equal (since the price of a big goat is higher). So, you had to fly up to 50 meters above and measure the weight of the topmost goat, 10 kg. The next goat weighed 20 kg. But, since the first goat is standing on top of this goat, 10 kg will be deducted. That is, the weight of the second goat is also 10 kg. Similarly, the weight of the third goat came to 30 kg. But, since there are two goats weighing 10 kg each on top of this third goat, 20 kg will be deducted. That is, the weight of the third goat is also 10 kg. Again, in the case of the 49th goat, you got a weight of 490 kg. But since there are 48 goats standing on top of it, 480 kg will be deducted. That is, the weight of the 49th goat is also 10 kg.

The same thing happens for the air column that is on top of that one square meter. The higher you go, the less the weight of the column becomes; and the weight of the column on the earth's surface is the highest, 10.3 tons. As a result, the pressure of this air column is also less in the upper direction and more in the lower direction and highest on the earth's surface. That is, since the weight is less in the upper direction, the pressure is also less and since the weight is more in the lower direction, the pressure is also higher. But fluids always flow from high pressure zone to low pressure zone. Then, it should be that the air or water at the bottom of the sea (like the atmosphere, the water pressure at the bottom of the sea is also higher) should go from the high-pressure place below to the low-pressure place above (and if your weight decreases, say becomes like a paper plane, then it should take you along with it. And voila, space travel for free). But the gravitational force of our earth prevents this from happening (this earth always causes trouble. It does not even let me do space travel for free. What's its problem man?). But if this gravitational force-induced obstacle was much higher, then it would have created a thin but excessively dense shell-like covering around our atmosphere. Which might have been unsuitable for life. So, there needs to be a balance between the earth's gravity and the upward pressure of air, and that balance exists on earth.

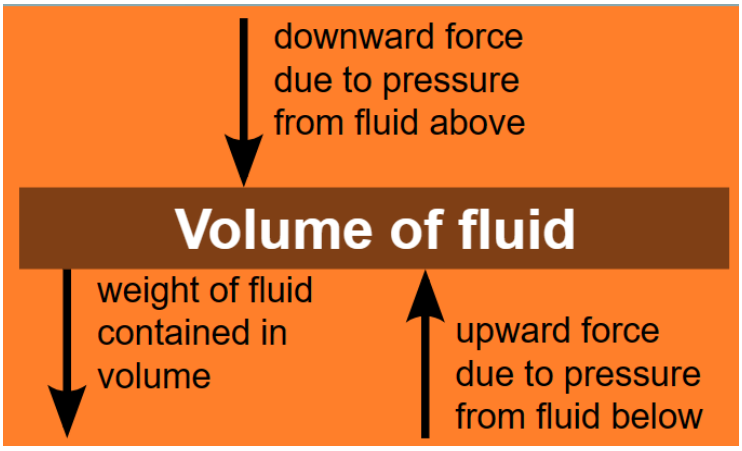


Figure 2: If the forces upwards and the forces downwards are equal, an object achives hydrostatic equilibrium

And this balance is, what my friends we call as the hydrostatic equilibrium. That is, the tons of water that are flowing towards the Bay of Bengal every day through the Padma River do not break the hydrostatic equilibrium. Because, this water is flowing sideways relative to the vastness of the earth, not up or down. [3][4]

However, our earth is not unique in this regard. You don't have to be very big to have hydrostatic equilibrium. Even Pluto, which is smaller than our moon (radius 1737.4 km), has hydrostatic equilibrium. [6] But even though our earth is not unique in this regard, if there were no hydrostatic equilibrium here, life on earth (perhaps) would not have been possible.

Anyway, hydrostatic equilibrium is a huge topic. It determines how much fluid will be in a star or planet or even a galaxy cluster. In fact, using the principle of hydrostatic equilibrium, we can determine the velocity dispersion of dark matter in galaxy clusters. [5]

1. [Basri, Gibor; Brown, E. M. (May 2006). "Planetesimals to Brown Dwarfs: What is a Planet?". *Annual Review of Earth and Planetary Sciences*. **34**: 193–216. arXiv:astro-ph/0608417. Bibcode:2006AREPS..34..193B. doi:10.1146/annurev.earth.34.031405.125058. S2CID 119338327]

2. Larramendi, A. (2016). "Shoulder height, body mass and shape of proboscideans" (PDF). *Acta Palaeontologica Polonica*. **61** (3): 537–574. doi:10.4202/app.00136.2014. S2CID 2092950. Archived (PDF) from the original on 24 August 2016. Retrieved 30 August 2016.

3. Hydrostatic Equilibrium and the Homogeneous Atmosphere; Hydrostatic equilibrium (sdsu.edu); Hydrostatic equilibrium (archive.org);

4. Vallis, Geoffrey K. (6 November 2006). *Atmospheric and Oceanic Fluid Dynamics: Fundamentals and Large-scale Circulation*. ISBN 9781139459969.

5. Weinberg, Steven (2008). *Cosmology*. New York: Oxford University Press. pp. 70–71. ISBN 978-0-19-852682-7.

6. Library of Congress; Why is Pluto no longer a planet? | Library of Congress (loc.gov); Why is Pluto no longer a planet? | Library of Congress (archive.org);

Planet? Where's her ID?

That is, a celestial object with planetary mass is not necessarily a planet. Poor Pluto, everyone gets promoted and Pluto gets demoted. The demotion happened in 2006. But what did Pluto do wrong that the creatures named *Homo sapiens* on this planet called Earth removed this helpless heavenly object named Pluto from the list of planets?

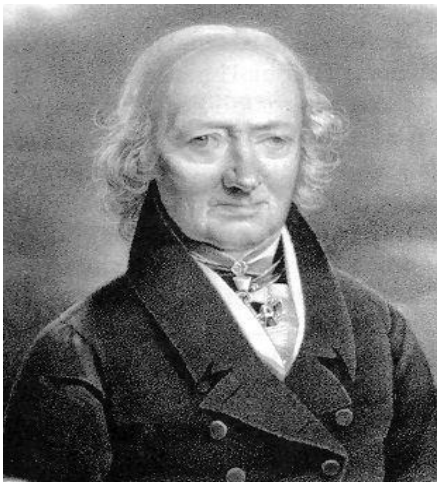


Figure 1: Johann Elert Bode

I first thought of starting from 1802, but after a lot of thinking (if you call that thinking), I started from 1766. Johann Daniel Titius added two paragraphs of his own while translating Charles Bonnet's work in 1766, in the first part of which he showed a relationship between the distances of the planets from the sun in the solar system. Later, Johann Elert Bode, in 1772, cited Titius in a footnote of his 'Anleitung zur Kenntniss des gestirnten Himmels' ('Guide to the Knowledge of the Starry Sky') and thus the relationship given by Titius became popular, which later became known as the Titius–Bode law, even as Bode's Law (what happened!). In fact, David Gregory showed a relationship between the distances of the sun and the planets in a book written in 1702. In 1726, Christian Wolff wrote about the distance between the sun and the planets in a book. Wolff probably took that part from Gregory's book. Titius said in a book, in the year of 1783, "This relationship of distance was shown by Christian Wolff, a German physicist, forty years ago." In 1784, Bode acknowledged Titius for his footnote citation. J. F. Wurm was the first person to give Bode's law an algebraic form. [1]

Figure 2: William Herschel

Year 1781, astronomer William Herschel, while trying to make a list of double stars, saw a disk-like celestial object in the night sky. Double stars are two stars that appear very close to each other visually. They may be binary systems (or binary stars: star systems where there are two stars. There is only one star in our solar system, the sun) or they may just look that way, i.e., an optical illusion, not part of any binary system. Anyway, Herschel was not the first person to see that object. Hipparchus, a Greek astronomer, probably mentioned Uranus (of course, the name Uranus was given much later) as a star in his star catalogue in 128 BC. Since then, many have observed Uranus, but they all called it a star. [2] [3] [4]

But why did they call Uranus a star? Actually, because the stars are so far away from the earth, they look like points of light to the naked eye. But at that time, the five discovered planets (six including Earth) looked like disks or circles even to the naked eye. Also, while the stars do not change their position in the sky (we now know that the stars do change their position, but it is so slow that it is not noticeable), the planets do change their position. But in the case of Uranus, the planet is so far away that it looks like a point of light to the naked eye. Also, because it rotates around the sun very slowly, it seems to be stationary in the sky unless you pay close attention. [5] [6]

Figure 3: A comet pictured in 2007 from Australia

Finally, in 1781, William Herschel saw that although Uranus looks like a point to the naked eye, when magnified with a telescope, it looks like a disk and it changes its position in the sky. Herschel declared it as a comet. [7]

When a comet passes near the sun, it heats up and gas escapes from the comet, creating a halo around it that can be seen from Earth. This halo can be thousands, even millions of kilometers wide and in some cases larger than the sun. This halo is called a coma, which comes from the Greek word kome, meaning hair, as the comet looks like a tuft of hair. The Greek word kometes, meaning long-haired star, comes from this word kome, from which the English word comet is derived. [8] [9] [10]

Herschel called Uranus a comet because discovering a comet was not a new thing at that time. But a new planet? After the six planets that were discovered in prehistoric times, no new planet was discovered until 1781. But Herschel had his suspicion that it could be a planet because it had many features that did not match with comets. Finally, when Anders Johan Lexell showed that Uranus's orbit was almost circular, where comets' orbits are elliptical, Uranus was universally recognized as a new planet. And for Herschel's contribution, King George III granted him an annual allowance of 200 pounds on the condition that Herschel would move to Windsor so that the royal family could see the sky with Herschel's telescopes. [11] [12] [13]

Now it seems that Uranus is unluckier than Pluto. These *Homo sapiens* seem to have played with Uranus. They even demoted it from the star status and put it in the level of comets. And after a lot of struggles, Uranus got promoted to the list of planets but never rose to the level of stars again. Oh man, what was their problem if they called Uranus a star? If someone did this to me that they have done to Uranus, I would have left this solar system and would have gone wherever my eyes focused. Thankfully, Uranus is an ice giant (a type of planet). Otherwise. . .

Anyway, Herschel named the newly discovered planet 'Georgium Sidus' or 'George's Star', after King George III. But his name failed to get popularity. [13] [14]

Bode, that Johann Elert Bode named the planet Uranus in 1772, after the Greek god of the sky in Greek mythology. Bode said that since Saturn (the planet Saturn) was Jupiter's father according to Greek mythology, the name of this new planet should be Uranus because Uranus was Saturn's father (from the perspective of distance from the sun among these three planets, Jupiter is closest to the sun, then Saturn and then Uranus). And this name became popular among everyone. [15] [16]

(I don't understand why everyone likes Bode so much. In 1772, he mentioned a law and his name was attached to that law! And in 1782, he named a planet and everyone rejected the name given by the discoverer of that planet and accepted Bode's name. Oh lord!)

Figure 4: Franz Xaver von Zach

After the discovery of Uranus, it was seen that, according to Bode's law or Titius-Bode law, if there is any planet after Saturn, then its location is exactly where Uranus is located. This endowed more credibility to Bode's law. In 1596, Johannes Kepler wrote, "I place a planet between Jupiter and Mars." According to Bode's law, there should also be a planet between the orbits of Mars and Jupiter. So, in 1787, Franz Xaver von Zach, a Hungarian astronomer, started looking for that planet and kept observing the night sky. [17] [18]

In 1796, von Zach organized a conference on that mysterious planet. In this conference, Joseph-Jérôme de Lalande said that if several astronomers were asked to observe different parts of the night sky, then the work that von Zach had started could be finished quickly. But nothing happened for several years. Finally, in September 1800, when von Zach visited the Observatory of Lilienthal and met five astronomers, they formed a group of 24 members to look for that planet, named Celestial Police (now don't you assume that the members of this police force were from the heaven, or in a bookish language you might call celestial people) or Lilienthal Detectives. [18]

However, according to another source, in 1787, von Zach started looking for that planet. Von Zach traveled to Celle, Bremen and Lilienthal in the winter of 1799 and met those five astronomers and then thought of working together to find that planet. For this purpose, on September 21, 1800, six astronomers met in Lilienthal and formed a group of 24 members called 'Vereinigten Astronomischen Gesellschaft' (in English, United Astronomical Society). This group became popular as Celestial Police. [19]

Figure 5: The discoverer of Ceres, Giuseppe Piazzi

Again, according to another source, in 1783, when von Zach met William Herschel, the discoverer of Uranus, at the age of 29, they discussed various topics along with the validity of Bode's law after the discovery of Uranus. Within two years, in 1785, von Zach determined the possible location of the planet's orbit between Mars and Jupiter. Then in 1798 he organized the first astronomical conference (note that the first source says that it was in 1796) and discussed various topics along with the planet between Mars and Jupiter. Inspired by this conference, von Zach dedicated himself to finding that planet. In 1799 he met several astronomers and decided that it would be better to work together to find the planet. For this purpose, on September 21, 1800, von Zach and six other astronomers met in Lilienthal and formed a group of 24 members called 'Vereinigten Astronomischen' Gesellschaft (in English, United Astronomical Society). This group became popular as Celestial Police. [20] [21] [22]

Another source says that some preliminary meetings were held at the Observatory of Lilienthal from September 13 to September 20 by those six people. [23]

One of the twenty-four experienced astronomers in this group was Giuseppe Piazzi. He was both a mathematician and a Catholic priest. And it was Piazzi who first saw an object between the orbits of Mars and Jupiter. The year was 1801 and the date was January 1 (finally! I didn't think I would have to write so much when I began from 1776). He had not yet received any invitation to join the Celestial Police. In fact, von Zach did not even send him an invitation letter. In a letter sent to Barnaba Oriani on May 29, 1801, von Zach invited Oriani to join the Celestial Police and asked Oriani to invite Piazzi too on behalf of the Celestial Police. Ironically, by then, almost everyone, including von Zach, had learned of Piazzi's discovery of the object between Mars and Jupiter. [24]

Let's go back to our story. Like Herschel, Piazzi was also working on a star catalogue. One source says that on January 1, 1801, he was looking for 'the 87th star of the Catalogue of the Zodiacal stars of Mr la Caille'. [25] But another source says that Piazzi mistakenly said in his first monograph that he was looking for the 87th star of the Catalogue of the Zodiacal stars of Mr la

Caille. In fact, he was looking for Francis Wollaston's Mayer 87 star and at that while doing so, accompanied by his assistant Niccolò Cacciatore, he noticed Lacaille 87 star and Ceres. [26]

Figure 6: Palermo Astronomical Observatory, from where Ceres was discovered

They were both at the Palermo Astronomical Observatory. Piazzi thought Ceres was a star too, just as Hershel did with Uranus. But when he observed it the next night, he saw that Ceres had changed its position. Piazzi was a little annoyed and thought that Niccolò Cacciatore had made some mistake in recording the position of the star the previous night. The same situation repeated the next night and the night after that. Piazzi then realized that it was not Cacciatore's fault. Piazzi sent a notice with his first four nights of observation to Journal de Paris and in February 1801, Journal de Paris published on January 15 that a new comet had been discovered at the Palermo Observatory on January 1.

Piazzi measured the position of that object 24 times from January 1 to February 11, 1801 and could not find the object again after February 11 due to illness and bad weather. However, there was also a human error behind losing this object. Even though Piazzi was ill, his assistant Niccolò Cacciatore could easily have found Ceres. In fact, Piazzi did not even mention Cacciatore when describing his discovery. [25] [27] [28]

Figure 7: Piazzi's assistant Niccolò Cacciatore

Here is an interesting incident to mention. The famous French astronomer Joseph-Jérôme de Lalande read this news in Journal de Paris and wrote to von Zach about this discovery in a letter. But von Zach thought that Piazzi had told Lalande about his discovery himself. So, von Zach wrote in his journal Monatliche Correspondenz (this was the first journal entirely dedicated to astronomy in the world; Von Zach founded it in 1800) in June 1801 issue that the first person whom Piazzi had informed about his discovery was Lalande. [29]

In reality, Piazzi wrote to his friend Barnaba Oriani and Johann Bode, these two people, about his discovery for the first time on January 24, 1801. Due to the difficulties of war, Bode received the letter two months later, on March 20, and Oriani received his letter on April 5. Many historians write that Piazzi wrote to Oriani, Bode and von Zach on the 23rd and it took three months for the letter to reach Bode. But this is not correct. [30] [31] [32]

In the letter he wrote to his friend Oriani, Piazzi said that although he called his discovered object a comet, he did not see any nebulosity (the coma of a comet) in it (meaning he saw a point-like object changing its position). He also noticed that the object's motion was very slow

and uniform. So, he told Oriani that this object could be something better than a comet (meaning a planet, but he did not mention the word, planet). However, in the letter he wrote to the German astronomer Johann Bode, Piazzi referred to the object as a comet and only mentioned that he did not see any nebulosity in it.

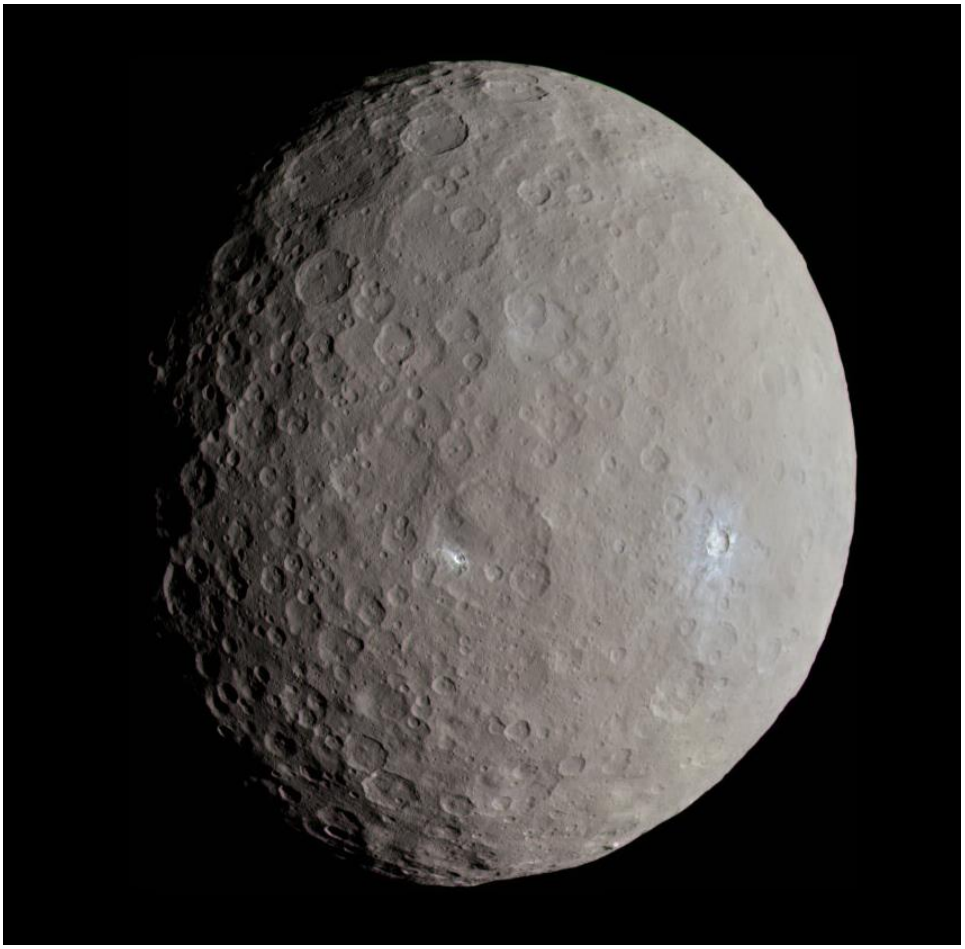


Figure 8: Picture of Ceres taken from a spacecraft

Piazzi did not send his observation details in these letters. In the meantime, Lalande read about the new comet discovered at the Palermo Observatory in Journal de Paris and asked Piazzi (Piazzi was the director of the Palermo Observatory at that time) to send him the details of the discovery. Piazzi received Lalande's letter in early April, but Piazzi had not yet received any reply from Oriani or Bode. Piazzi sent his observation data to Lalande and Oriani on April 11 of 1801. [24] Bode did not receive Piazzi's observation details until June 11. [30]

Lalande's colleague, Johann Burckhardt, used Piazzi's data sent to Lalande to calculate circular and elliptical (another source says hyperbolic) orbits for the object. [33] [24] Von Zach, Olbers and Piazzi calculated circular orbits for the object. Since Piazzi failed to find the object again after February 11, astronomers tried to find it again by calculating an orbit.

Bode received Piazzi's letter on March 20, 1801 (Oriani received it on April 5) and on March 26, at the last meeting of the Royal Academy of Sciences (also known as Prussian Academy of Sciences) before the Easter holiday, he talked about this discovery. He then continued his calculations based on the information Piazzi had shared with him in his letter and wrote a letter to von Zach on April 14. In this letter, Bode claimed that he had calculated and found that Piazzi's object was not a comet but the planet between Mars and Jupiter and wanted to know

von Zach's opinion on this. After Easter, he also said the same thing at Prussian Academy of Sciences. [33] [24]

Von Zach wrote in a letter sent to Oriani on May 29, 1801, 'How can Bode say from just a few numbers that it is a planet? … I do not believe Bode's words. … Since Piazzi sent letters to Oriani and Bode on the same date (January 24), is it possible that Piazzi told Oriani in his letter that it could be a planet but did not mention that to Bode? Piazzi must have told Bode about his doubts, but Bode is hiding it so that he can get the credit for being the first man to call this a planet. …' [35] (As I said before, Piazzi did not tell Bode about his doubts. What is Mr. von Zach's problem? He first thought that Piazzi first told Lalande about his discovery. And then he concepted that Piazzi told Bode about his doubts!)

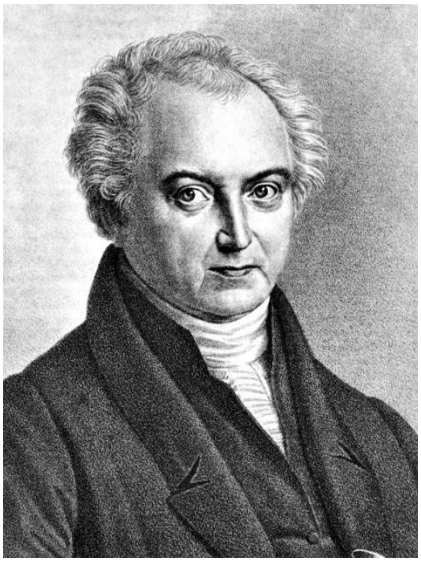


Figure 9: Heinrich Wilhelm Olbers

Bode named the object Juno in May of that year. And von Zach said it should be called Hera and even lebeled Bode a 'donkey'! When Oriani told Piazzi about this on July 25, Piazzi said in a letter on August 25, 'If the Germans think they have the right to name someone else's discovery, let them call it whatever they please. We will call it Ceres.' Piazzi actually told Oriani in a letter on May 7, 1801, that he wanted to name the newly discovered object 'Cerere Ferdinandea' (Cerere is Ceres in English) in honor of Ceres, the patron goddess of Sicily, and Ferdinandea, his patron king Ferdinand. By the way, everyone later accepted the name given by Piazzi. However, von Zach said in a letter to Oriani on February 15, 1802, 'Napoleon Bonaparte wants to call this new planet Juno and Lalande wants to call it Piazzi. I will call it Ceres and ask Piazzi to drop the Ferdinandea part. It is too long for a name.' Piazzi remained firm in his decision. However, as time went by, the Ferdinandea part lost its popularity and disappeared slowly. It is now known as Ceres. [24] [36] [37]

Anyway, as I was saying, astronomers were trying to determine an orbit for the object. As I said before, many people made different kinds of orbits. But, Piazzi published his observation details rather late. Von Zach wrote in the September 1801 issue of Monatliche Correspondenz that Piazzi was hiding this data deliberately so that he could get all the credit for determining the orbit of this object. Moreover, there was a mistake in Piazzi's observation data. As a result, astronomers went a little astray. Von Zach hinted to Oriani in a letter dated July 6, 1801 that he anticipate that Piazzi's mistakes were not accidental! But to tell the truth, when von Zach found the object again in December of that year, Zach's values of the object's position were worse than Piazzi's observation data. [38]

Whatever, as the days went by, almost everyone began accepting that Piazzi's discovered object was a planet. In the meantime, Monatliche Correspondenz published Piazzi's complete observation details in its September 1801 issue and this caught the eye of 24-year-old (another

Figure 10: Prince of mathematics, Carl Friedrich Gauss

source says 23) Carl Friedrich Gauss. Gauss's teacher Eberhard Zimmermann informed him about Piazzi's discovery published in the Monatliche Correspondenz and Gauss calculated an orbit for Piazzi's object in just one month. Using Gauss's calculation, several astronomers began searching for Piazzi's object in the night sky. And Von Zach rediscovered the object on December 7th and on January 1, 1802, exactly one year after the discovery of Ceres, he confirmed that the object was in fact Ceres. [39] [24]

Now the question is, is Ceres really a planet? Or is it not a planet? Many accepted that it was a planet, but some people had doubts. Ceres was not very bright in the sky. The only reason for an object between Mars and Jupiter to be not bright could be that the object is very small. [40]

In the meantime, on March 28, 1802, while observing Ceres, Heinrich Olbers discovered Pallas. This object was first called Olbersiana, after the discoverer. But Olbers objected (If I were in the place of Olbers, I would have… maybe that's why I'm not) and named it Pallas. Von Zach wrote to Piazzi on April 8, 1802, mentioning that Pallas was a planet and praised Piazzi, saying that if Ceres had not been discovered, Pallas would not have been discovered either. [24] [41]

Although Pallas's position was very close to Ceres's, Pallas's orbit was more parabolic. That is, more like a comet. Johann Schroeter observed Pallas since two days after its discovery and concluded at the end of April that Pallas's orbit was too parabolic. So, it could not be a planet. But Gauss said he had no objection calling Pallas a planet. On the other hand, Bode did not accept that Pallas was a planet. (If there were two planets in the same position, Bode's law would be proved wrong!) However, Bode later said, "if the object returned to its position calculated with its elliptical motion the following year, we would have to admit that it is a planet. In that case, there would be two planets where I thought there was only one and this would not destroy the relationship (Bode's law) between the distances of the planets." [42]

Meanwhile, William Herschel also started poking into Ceres and Pallas. He measured the diameters of both Ceres and Pallas and found Ceres's diameter to be 162 miles and Pallas's diameter to be 147 miles (in reality, the diameters of the two planets are 584 miles and 319 miles respectively). Herschel's opinion was that Ceres and Pallas were not planets. [43]

So, on April 25, 1802, Herschel sent a letter to his friend William Watson. Herschel wrote in the letter, 'These two objects are certainly moving around the sun, like comets or meteors. Their orbits are elliptical (according to Kepler's law, the orbits of planets are elliptical. Most comets' orbits are also elliptical but because their orbits are very long, they seem parabolic). We know

that some comets' orbits are also elliptical. But the difference is that these objects are very small compared to planets and their orbits are inclined. If we take their orbits as part of the ecliptic and then more new objects with more inclined orbits are discovered then this whole sky will become the ecliptic one day, which will be absurd… We should give these objects a new name… I am writing a paper about them. If you can, help me find a new name for these objects.' [44]

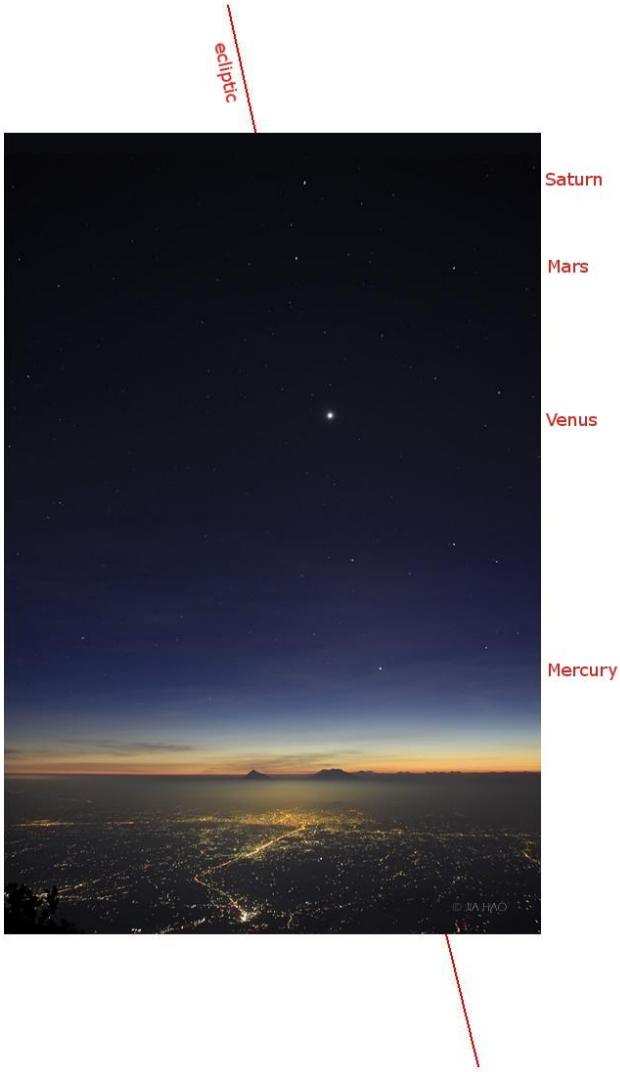


Figure 11: Four planets on the same line of the ecliptic

Let me clarify something here, as the Earth moves around the Sun, it seems to us that the Sun is moving eastward within the confines of the zodiac. This imaginary path of the Sun is called the Ecliptic. Almost all the planets lie within a range of about 8 degrees on either sides of this Ecliptic. (Why so? I may have left it for the next chapters) But, Ceres and Pallas are located somewhat obliquely to the ecliptic. [45] [46]

Whatever, Watson sent several names to Herschel but unfortunately Herschel was not satisfied with any of them. Herschel, on May 3, 1802, sought Charles Burney Senior's assistance to come up with an appropriate name for his discovery. Burney Sr wrote a letter to his son Charles Burney Jr on that day (although, Burney Senior perhaps, mistakenly put the date as May 10) about finding a new name. Now, Burney Jr was an expert in ancient Greek. Burney Junior considered that the name should be asteroid, which means 'star-like'. Herschel used the term asteroid to describe Ceres and Pallas in his paper published on 6 May 1802. However, Herschel was not entirely happy with the term asteroid. Therefore he asked Sir Joseph Banks for advice on a new name. Banks wrote a letter to Herschel on July 7, 1802, mentioning some new names stating that he had requested Stephen Weston for new names and that Weston had made a list of names. But in the end, Herschel chose the name asteroid anyway. [49]

For years, Herschel had been credited with coining the term asteroid. However, 200 years later, it has been proven that it was not Herschel, but Burney Jr who coined the word Asteroid. (Oh my! Did Uranus cursed Herschel for what he did to Uranus? Why else woud he be discarted from the credit of coining the term asteroid after 200 years?) One interesting point worth

mentioning here is that Carl Linnaeus first used the word in botanical sense in 1767, which Barnard Junior was unaware of. [47] [48]

Within ten days of discovering Pallas, Ferdinand von Ende, one of Olbers' friends, wrote a letter to Olbers. Ende stated that instead of finding one planet, they had found two smaller planets. Consequently, some might think that these two small planets were once part of a larger planet split in half by a comet's impact. However, Ende added that this was just a fantasy.

Figure 12: Karl Ludwig Hencke

Two weeks later, Olbers said much the same thing in a letter to Gauss. Wolbers suggested that a collision with a comet might not be that unlikely, and proffered an equation too. On May 17, 1804, Olbers sent Herschel a letter, discussing this idea and indicating that if Ceres and Pallas were fragments of a larger planet, it was probable that many more such fragments lay in that vicinity. In the end, however, Wolbers said that his idea was just a hypothesis. Many astronomers embraced Olbers' hypothesis though.

Subsequently, Juno and Vesta were discovered in 1804 and 1807 respectively by Karl Ludwig Harding and Heinrich Olbers. Their orbits were also at similar distances from the sun as Ceres. This further supported Olbers' hypothesis. However, at that time, the list of planets in various books included Ceres, Pallas, Juno and Vesta. That is, the number of planets reached 11 (note, Neptune and Pluto had not been discovered yet). [48] [50] [51] [52] [53]

After the discovery of Vesta in 1807, no new asteroids were discovered for almost forty years. One reason for this was that many astronomers followed Olbers' hypothesis and searched only in a small area (according to Olbers' hypothesis, planet debris had to be found in a small area).

Anyway, finally, in the December of 1845, after his search since 1830, German astronomer Karl Ludwig Hencke discovered the fifth asteroid. Hencke discovered another asteroid in 1847 and bestowed the honor of naming the asteroid to Carl Friedrich Gauss, who was the last of the first generation of asteroid researchers. And between these two years, Neptune was discovered in 1846. After Hencke's discovery, the number of new asteroids continued to increase rapidly, even there have been incidents of discovering two asteroids by the same astronomer on the same night. From there on, the term 'asteroid' started getting popularity. [54] [55]

The discovery of Neptune, however was another wonder. Neptune is not visible to the naked eye. In 1612, Galileo Galilei used his telescope to observe Neptune for the first time (of course, the name Neptune was not given until after 1846), however he thought it was a fixed star. Long after the discovery of Uranus, in 1821, Alexis Bouvard, while calculating the orbit of Uranus, found that according to Newton's law of gravity and motion, Uranus was not following the orbit it was supposed to be moving on. A that, he surmised that there might be a planet near Uranus whose attraction was causing this deviation in Uranus's orbit. [56] [57] [58]

Figure 13: The largest 42 asteroids

Then, in 1843, the British mathematician John Couch Adams and in 1845, the French astronomer Urbain-Jean-Joseph Le Verrier made separate attempts to locate the planet. Based on Adams' calculation, James Challis and based on Le Verrier's calculation, Johann Gottfried Galle and his assistant Heinrich Louis d'Arrest searched for the planet and finally in 1846 Galle and Louis d'Arrest discovered Neptune. However, Chalice had glimpse of neptune before Galle, and Louis d'Arrest, but unfortunately did not realize that it was the same planet. There was a long-standing dispute between the British and the French over Neptune, but finally both Adams and Le Verrier were credited for the discovery of the planet. However, new research suggest that Adams' calculations were far more misleading and that the British tried to hide it. [59] [60]

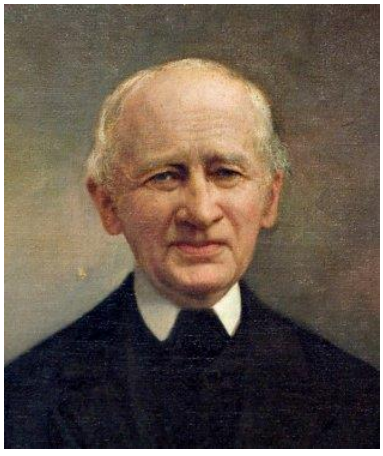


Figure 14: Johann Gottfried Galle

Again, one source says that Galileo may have been the first to notice that Neptune was not a fixed star. However, it is not certain whether Galileo suspected that the object he saw was a planet. [61]

Imagine, what would be the consequences if it is proven that Galileo thought that Neptune was a planet. Then the credit for discovering the first planet with a telescope, which right now belongs to Herschel, would be given to Galileo. The credit for coining the word asteroid has

been taken away from Herschel after two hundred years anyway and then if … You know what, I've learned my lesson. You should never play games with a planet, whether you are doing it willingly or unwillingly.

Anyway, noticing the discrepancy between Adams and Le Verrier's calculations, Benjamin Peirce said that the planet named Neptune that was discovered was not the planet that Adams and Le Verrier had calculated. Jacques Babinet taking these words in account said that there are actually two planets there, one of them is Neptune. And he named the other planet as Hyperion. [62]

Figure 15: Percival Lowell

Even after the discovery of Neptune, astronomers saw in around 1880 that there was still inconsistency in Uranus' orbit. So, it was assumed that there was another planet farther than Neptune that was causing this. [63] In 1892 Gabriel Dallet named the planet Planet X. In 1906 (another source says 1905), Percival Lowell began searching for Planet X. Lowell was a businessman. Lowell was born in 1855 and inspired by Giovanni Schiaparelli's discovery of Martian canals in the 1890s, he gave up everything and devoted himself entirely to astronomy. Lowell believed these canals were artificially made or, in other words, there is life on Mars. In pursuit of his interest in Mars, Lowell built his own observatory, although his research was not limited to Mars only and thus at one time, he came across the problem of Planet X. Lowell searched, calculated the location of the planet, but he did not manage to locate Planet X and died, not finishing his work in 1916. [64] [65] [66] However, Lowell left more than a million dollars for his observatory. After Lowell's death, his widow, Constance Lowell, engaged in a legal battle over Lowell's estate, and the work on Lowell's observatory was interrupted as a result. Later, a young amateur astronomer, Clyde Tombaugh, was assigned to look for Planet X at Lowell's observatory, and within a year, on February 18, 1930, Tombaugh discovered a planet very close to Lowell's calculated position. On March 13, the news of Tombaugh's discovery was announced to the public; it was Lowell's birth anniversary, and on this day, Uranus was discovered. There were countless suggestions for naming this planet. Constance Lowell, Percival Lowell's widow also suggested various names. Among them were Zeus (the ancient Greek god of sky and thunder), Percival and even Constance! [67] [68] [69] [70] [71] [72]

Figure 16: Clyde Tombaugh

Meanwhile, Venetia Burney, an 11-year-old resident of Oxford, learned about the discovery of Planet X from her grandfather Falconer Madan one morning. Falconer's elder brother was Henry Madan, who named the two moons of Mars, Deimos and Phobos. However, Henry had died almost 30 years ago (December 22, 1901).

So, in one morning in March 1930, Falconer was reading about the discovery of the ninth planet in the solar system in the morning newspaper while having breakfast. The newspaper even said that the planet might be bigger than our Earth, but ironically, Pluto is actually smaller than our Moon. Falconer thought the planet could be named Odin, but Venetia came to know about the planet that time and said that the new planet could be named Pluto. According to ancient Greek mythology, Pluto is the ruler of the Underworld, much like the ninth planet. The planet is as if the lord of the dark underworld far away from the sun. Moreover, the first two letters in Pluto's name, 'p' and 'l', are the same as those in Percival Lowell's first initials. But Venetia did not really link among these matches that morning. She only thought that there was no planet named Pluto, so a new planet could be named such. Venetia forgot about the incidents of that morning in the following months. But her grandfather Falconer told his friend Herbert Hall Turner about his granddaughter's suggestion and later Pluto was accepted officially by vote. [68] [73] [74]

Figure 17: 11-year-old Venetia Burney

Pluto, however, had already been spotted several times before Tombaugh's discovery, but no one actually guessed that it could be a planet. Even while Lowell was alive, the planet was observed twice in his observatory. Anyway, as the days went by, Pluto's true nature became more and more apparent that Pluto might not be the planet X. Although its location was very close to Lowell's estimate, its size was too small to cause any disturbance in Uranus' orbit. And its orbit was more elliptical than any other planet. Later, it was discovered that the lack of accuracy in Neptune's mass measurement caused this anomaly in Uranus's orbit. When Voyager 2 spacecraft flew past Neptune in 1989, the spacecraft accurately measured Neptune's mass and displayed that Uranus's orbit was indeed natural. It was our misjudgment that was fundamentally flawed. [75] [76] [77]

So far, I have talked about the discovery of Uranus, Neptune, Ceres and Pluto. Apart from Neptune, the discoveries of the other three heavenly bodies were coincidental events. They discovered Uranus and Ceres while looking for stars in the sky, and the discovery of Pluto occurred while searching for Planet X. (Even though I am slightly hesitant, I am taking the courage) Again, the hypothesis that Asteroids are broken pieces of a large planet is also not correct. However, what I feel to be the biggest coincidence, I'm going to hold that off for a little while longer.

Anyway, after Pluto, various celestial objects were discovered around it as happened with Ceres. These objects are so numerous that they create a belt-like structure. This structure is called the Kuiper belt. There is also a similar structure around Ceres called the asteroid belt. [78] [79] [80] After the discovery of the Kuiper belt, there rose skepticism about Pluto's status as a planet. Pluto's highly elliptical and oblique orbit were other sparks of doubt. This controversy was again fueled by the discovery of 2003 UB313 in 2005 by a team of astrophysicists led by Mike Brown. The object was more massive than Pluto, and it was initially

it was reported to be the tenth planet of our solar system. [81] The discovery of 2003 UB313 gave rise to even more doubt about Pluto's planetary status. If 2003 UB313 is a planet, then it cannot be named 2003 UB313; like other planets, it should be named after a major deity. On the heels of these speculations, the then IAU President Ron Eckers said, "It is not possible to name 2003 UB313 until we know for sure whether it is a planet or not." Following that, in 2006, the IAU set up a committee to define planets. In his explanation of this statement in 2018, Eckers referred to, "the naming of planets after major deities." However, Ceres or Juno are named after important deities with the same status as Mercury. Also, if 2003 UB313 is classified as a planet, Charon must also be called a planet, but Charon is not named after a god. Thus, the naming after important deities probably had little effect on the events of 2006. However, the news of the committee formed by the IAU was kept hidden from the general public and the media that time.

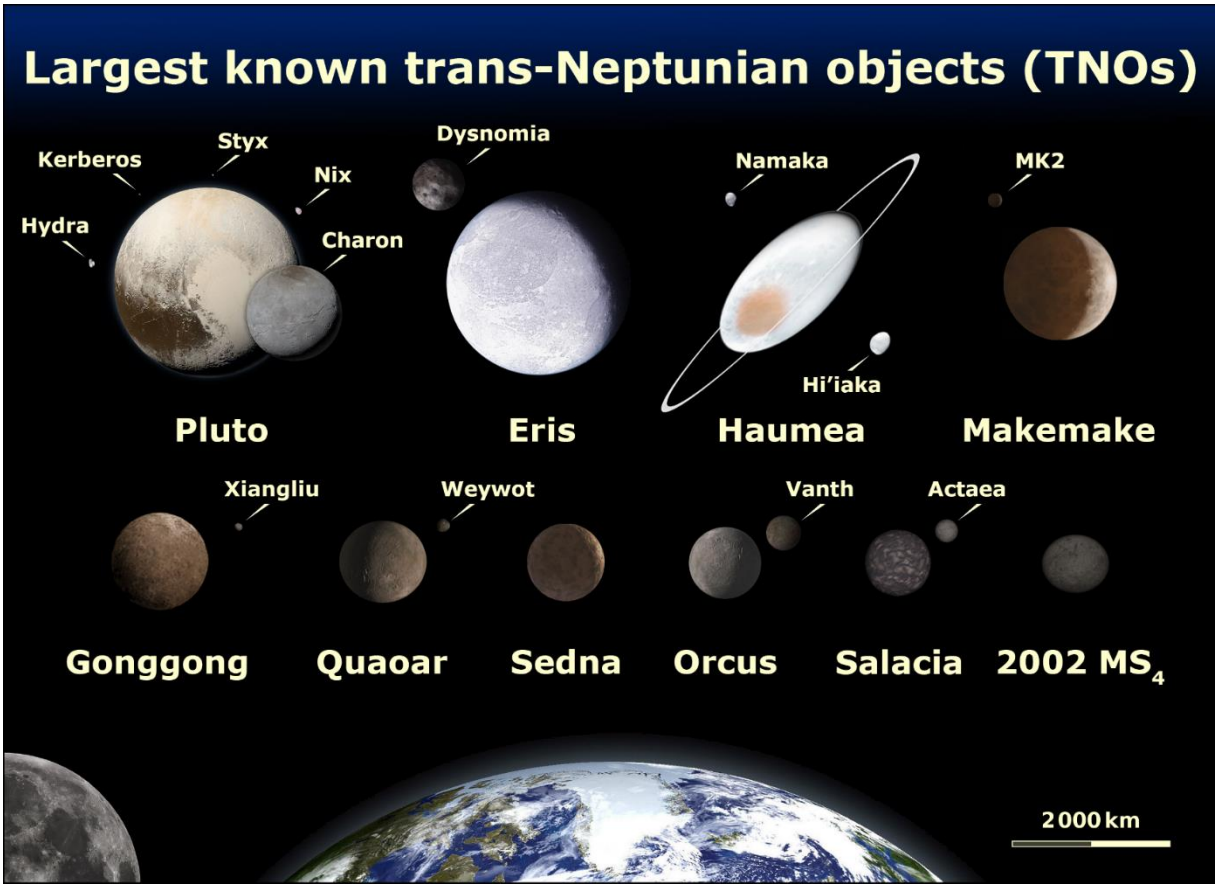


Figure 18: Solar system objects that are situated farther than Neptune from the sun

"We knew that exposing the committee would bring pressure from the media, which would affect our decision-making," Eckers said. " "Maybe our decision (to hide from the media) was wrong," Eckers later said. [71] [82] [83] [84] [85] [86]

Why did Eckers say such a thing? The committee's discussions were not disclosed to the media before the meeting was called to make the decision. The attendance at that meeting was very low for various reasons and one of them was delaying to inform the media about the issue of defining

the planets. In that meeting, another group besides the IAU committee also presented a definition. Some people at the meeting said that the general public would not accept any definition that increased the number of planets significantly. However, there is no record of whether there was any discussion on why the number of planets could not be increased. Anyway, a vote was held later and the proposal of the IAU committee was accepted. At the end of the meeting, the definition of a planet was given as follows:

1. They will orbit around the sun.
2. They must have hydrostatic equilibrium.
3. They must not have any other objects around their orbit. If there are any other objects, they will be under the control of the first object.

According to this definition, Pluto got excluded from the list of planets and the number of planets in the solar system became eight. (Pluto probably did not feel much sad. It did not die alone; it took Charon and 2003 UB313 with it. Moreover, it enjoyed some experience of being a planet for some days. And Tombaugh, the discoverer of Pluto, had already passed away) [83]

Many planetary scientists, however, did not accept the IAU's definition. The issues of reducing the number of planets or not having any other objects around their orbits has probably more cultural significance than scientific. Much like Herschel's thinking in the 1800s. Another thing to note is that Mercury is not completely in hydrostatic equilibrium! [47] [87]

So, if you really want to, you can call Pluto a planet!

And let me add another piece of information - 2003 UB313 was finally named Eris. Eris is the Greek goddess of 'discord and strife'. One of the discoverers of Eris, Mike Brown, said, "Eris caused quarrels, conflicts and divisions among people and so did it (2003 UB313 or Eris)."

And the biggest coincidence (to me) that I talked about was Bode's law. Yes, the same Bode's law that led to so many speculations about Ceres. It should have been mentioned earlier, but I hid it in an attempt to shock you. It was seen after the discovery of Neptune that Neptune's orbit does not follow Bode's law. After the discovery of Pluto, it was found that Boad's law cannot tie Pluto either. Then the Kuiper belt and Eris were discovered and as you might guess, their orbits also do not follow Bode's law. Thus, Bode's law gradually got demoted. At this time, many have tried to modify the law. One of them was Mary Blagg. In 1913, she published a paper in which she gave a refined form of Bode's law. Surprisingly, with this refined formula, not only the distance of the planets from the sun but also the distance of their satellites from the planets can be established. However, Blagg's modification was not flawless either. Research shows that some planets in other star systems also follow a similar (not exactly Bode's) law. But why the planets follow Bode's law still remains unknown. Many say it is just a mathematical coincidence! [88] [89] [90] [91] [92] [93] [94]

Why should I leave out the Vulcan? I remember reading a book as a child that listed the number of planets in our solar system as 11, with Pluto, X, and Vulcan as the three additional planets. Let me assure you, the book was written after 2007. So, since I discussed Pluto and X, I thought

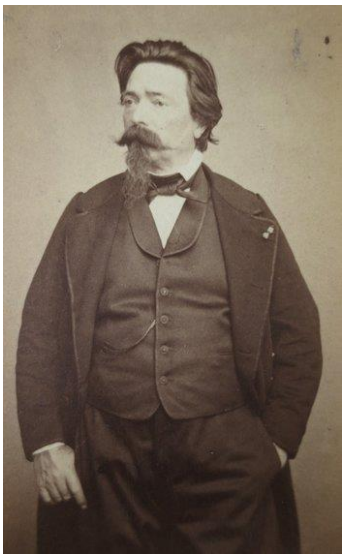


Figure 19: Edmond Modeste Lescarbault

I'd give Vulcan a little tap too. In 1838, Thomas Dick said, "There is no reason why a planet should not exist between Mercury and the Sun." In 1842, during a total solar eclipse, a solar prominence or filament was observed. A solar prominence is a portion of the Sun's surface that extends outwards. At that time, people didn't know what a solar prominence was. So Jacques Babinet suggested that it was something like a planet and named it Vulcan. Urbain Le Verrier, a French astronomer, calculated the orbit of Mercury at that time. Yes, Le Verrier, the same person who discovered Neptune by merely doing calculations at his desk. But when Mercury transited across the sun in 1845 and 1848, he found that his calculations did not match. But Le Verrier was undeterred. After much calculation, he came to the conclusion that there is in fact disturbance in Mercury's orbit and guessed that the existence of an object Mercury's orbit and sun could be responsible for the orbit's deviation. On September 12, 1859, he discussed his idea with his collaborator, Herve Faye. Earlier that same year, on March 26, a doctor, Edmond Modeste Lescarbault, while looking at the sky with his telescope at leisure as usual, saw an object above the sun. He observed the object so well at a time he went to see a patient and when he came back, he saw the object again. However, due to hesitations, Lescarbault did not reveal this to anyone. Later, when he read in a journal about Le Verrier's calculation of Mercury's orbital anomaly, he wrote a letter to Le Verrier on December 22, 1859. Receiving the letter, on December 30, Le Verrier himself went out to meet Lescarbault and spoke with him at Lescarbault's home. On January 2, 1860, Le Verrier revealed Lescarbault's observation to all at a meeting.

A festive atmosphere was created in France. Lescarbault was congratulated by the Royal Astronomical Society. They said, "To Lescarbault's credit, Le Verrier's theoretical explorations have once again won." He was also awarded the Legion of Honour. An American newspaper mocked the astronomers of the Harvard Observatory saying, "An amateur made such a discovery with a toy telescope. And these gentlemen of ours were perhaps sleeping at that time." Whatever, the object was named Vulcan, but it is not certain who actually named it. Unfortunately, the object observed by Lescarbault was never seen again, despite many searches. Even Emmanuel Liais, an astronomer who learned about Lescarbault's observation in February 1860, said that he (Liais) was looking at the sun from Rio de Janeiro with a telescope twice as powerful as Lescarbault's that specific time, but he saw nothing. Several astronomers claimed to have spotted Vulcan at various times, but it turned out that they had actually caught sight of some other object and not the Vulcan. [95]

Le Verrier died in 1877, perhaps thinking that he had discovered not one but two planets with the tip of his pen. However, as previously stated, Vulcan was not seen again. In 1891, Lescarbault, then 77 years old, claimed to have seen a new star that he had never seen before. But sadly, it was just Saturn! Three years later, in 1894, Lescarbault too passed away. The excitement regarding Vulcan had by then subsided. Finally, Albert Einstein showed in 1915 with

his famous theory of relativity that there is no anomaly in Mercury's orbit, but it is Newtonian mechanics where all the discrepancy lay in! And by this work, Einstein also obtained an experimental proof of his theory of relativity.

What Lescarbault saw for the first time is not known. After receiving the Legion of Honor, he did not appear into much discussion. And for Le Verrier? He is still referred to with the words as Francois Arago once said, "The man who discovered a planet with the point of his pen." [96] [97]

Figure 20: The man who discovered a planet with the point of his pen

1. Discovery of the First Asteroid, Ceres; Clifford Cunningham; DOI: 10.1007/978-3-319-21777-2; ISBN : 978-3-319-21776-5; page 11-19
2. René Bourtembourg (2013). "Was Uranus Observed by Hipparchos?". *Journal for the History of Astronomy*. **44** (4): 377–387. Bibcode:2013JHA....44..377B. doi:10.1177/0021828613044004 01. S2CID 122482074
3. *Is Pluto a Planet? A Historical Journey through the Solar System;* **David A. Weintraub; page 89;** Is Pluto a planet? : a historical journey through the solar system : Weintraub, David A. (David Andrew), 1958- : Free Download, Borrow, and Streaming : Internet Archive;
4. The Scientific Legacy of William Herschel; **Clifford Cunningham; 2018; ISBN : 978-3-319-32825-6; page 324**
5. Ancient Greek Astronomy and Cosmology | Modeling the Cosmos | Articles and Essays | Finding Our Place in the Cosmos: From Galileo to Sagan and Beyond | Digital Collections | Library of Congress (loc.gov); Ancient Greek Astronomy and Cosmology | Modeling the Cosmos | Articles and Essays | Finding Our Place in the Cosmos: From Galileo to Sagan and Beyond | Digital Collections | Library of Congress (archive.org)
6. Uranus: the first planet discovered with a telescope | Science Museum; Uranus: the first planet discovered with a telescope | Science Museum (archive.org);
7. Herschel, William; Watson, Dr. (1781). "Account of a Comet, By Mr. Herschel, F. R. S.; Communicated by Dr. Watson, Jun. of Bath, F. R. S". *Philosophical Transactions of the Royal Society of London*. **71**: 492–501. Bibcode:1781RSPT...71..492H. doi:10.1098/rstl.1781.0056. S2CID 186208953
8. Harper, Douglas. "Comet (n.)". *Online Etymology Dictionary*. Retrieved 30 July 2013.
9. Clay Sherrod, P. & Koed, Thomas L. (2003). *A Complete Manual of Amateur Astronomy: Tools and Techniques for Astronomical Observations*. Courier Corporation. p. 66. ISBN 978-0-486-15216-5.
10. Lallement, Rosine; et al. (2002). "The Shadow of Comet Hale–Bopp in Lyman-Alpha". *Earth, Moon, and Planets*. **90** (1): 67-76. Bibcode:2002EM&P...90...67L. doi:10.1023/A:1021512317744. S2CID 118200399
11. *Is Pluto a Planet? A Historical Journey through the Solar System;* **David A. Weintraub; page 90-91;** Is Pluto a planet? : a historical journey through the solar system : Weintraub, David A. (David Andrew), 1958- : Free Download, Borrow, and Streaming : Internet Archive;
12. Kuhn, Thomas S. (1970). *The structure of scientific revolutions*. Chicago: The University of Chicago Press. p. 115. ISBN 978-0226458045.
13. Schaffer, Simon (1981). "Uranus and the Establishment of Herschel's Astronomy". *Journal for the History of Astronomy*. **12**: 11–25. Bibcode:1981JHA....12...11S. doi:10.1177/002182868101200102. S2CID 118813550.
14. "Voyager at Uranus". *NASA JPL*. **7** (85): 400–268. 1986. Archived from the original on 10 February 2006.
15. Daugherty, Brian. "Astronomy in Berlin". Brian Daugherty. Archived from the original on 8 October 2014. Retrieved 24 May 2007.

16. Planets beyond : discovering the outer solar system : Littmann, Mark, 1939- : Free Download, Borrow, and Streaming : Internet Archive; page 10;

17. *Is Pluto a Planet? A Historical Journey through the Solar System;* **David A. Weintraub; page 94-95;** Is Pluto a planet? : a historical journey through the solar system : Weintraub, David A. (David Andrew), 1958- : Free Download, Borrow, and Streaming : Internet Archive;
18. *Is Pluto a Planet? A Historical Journey through the Solar System;* **David A. Weintraub; page 96;** Is Pluto a planet? : a historical journey through the solar system : Weintraub, David A. (David Andrew), 1958- : Free Download, Borrow, and Streaming : Internet Archive;
19. BODE'S LAW AND THE DISCOVERY OF CERES (unipa.it); BODE'S LAW AND THE DISCOVERY OF CERES (archive.org);
20. Cunningham, Clifford. "Franz Xaver von Zach". Encyclopedia Britannica, 29 Aug. 2022, https://www.britannica.com/biography/Franz-Xaver-von-Zach. Accessed 30 November 2022.)
21. Discovery of the First Asteroid, Ceres: Historical Studies in Asteroid Research | SpringerLink; Cunningham, Clifford; page 8 and 19-23;

22. Internationalität von der VAG (1800) bis zur Astronomischen Gesellschaft - NASA/ADS (harvard.edu); Internationalität von der VAG (1800) bis zur Astronomischen Gesellschaft;Internationalität von der VAG (1800) bis zur Astronomischen Gesellschaft;Internationality from the VAG (1800) to the Astronomische Gesellschaft. - NASA/ADS (archive.org); Wolfschmidt, Gudrun; Acta Historica Astronomiae, vol. 14, p. 182-203.
23. Franz Xaver von Zach (1754-1832) : his life and times in SearchWorks catalog (stanford.edu); Magda Vargha ; translated by József Csaba; page 48 and 54;
24. (PDF) Giuseppe Piazzi and the Discovery of Ceres (researchgate.net); G. Foderà Serio, A. Manara, P. Sicoli;
25. BODE'S LAW AND THE DISCOVERY OF CERES (unipa.it); BODE'S LAW AND THE DISCOVERY OF CERES (archive.org);
26. Discovery of the First Asteroid, Ceres: Historical Studies in Asteroid Research | SpringerLink; Cunningham, Clifford; page 29 and 31;
27. Discovery of the First Asteroid, Ceres: Historical Studies in Asteroid Research | SpringerLink; Cunningham, Clifford; page 139;
28. Asteroids, Cunningham (uchicago.edu); Cunningham, Clifford; page 11-13;
29. Discovery of the First Asteroid, Ceres: Historical Studies in Asteroid Research | SpringerLink; Cunningham, Clifford; page 19 and 29;
30. Discovery of the First Asteroid, Ceres: Historical Studies in Asteroid Research | SpringerLink; Cunningham, Clifford; page 29 and 35;
31. 1971JHA.....2..195F Page 195 (harvard.edu); Gauss and the Discovery of Ceres; Forbes, E. G.; Journal for the History of Astronomy, Vol. 2, p.195;
32. *Is Pluto a Planet? A Historical Journey through the Solar System;* **David A. Weintraub; page 97;** Is Pluto a planet? : a historical journey through the solar system : Weintraub, David A. (David Andrew), 1958- : Free Download, Borrow, and Streaming : Internet Archive;

33. Discovery of the First Asteroid, Ceres: Historical Studies in Asteroid Research | SpringerLink; Cunningham, Clifford; page 41-43;
34. Discovery of the First Asteroid, Ceres: Historical Studies in Asteroid Research | SpringerLink; Cunningham, Clifford; page 135-137;
35. Discovery of the First Asteroid, Ceres: Historical Studies in Asteroid Research | SpringerLink; Cunningham, Clifford; page 257;
36. (PDF) How the first dwarf planet became the asteroid Ceres (researchgate.net); January 2009; Journal of Astronomical History and Heritage; 12(3):240-248; DOI:10.3724/SP.J.1440-2807.2009.03.07; Clifford J. Cunningham, Brian G. Marsden and Wayne Orchiston
37. Discovery of the First Asteroid, Ceres: Historical Studies in Asteroid Research | SpringerLink; Cunningham, Clifford; page 57-58 and 285-286;
38. Discovery of the First Asteroid, Ceres: Historical Studies in Asteroid Research | SpringerLink; Cunningham, Clifford; page 35-37;
39. Discovery of the First Asteroid, Ceres: Historical Studies in Asteroid Research | SpringerLink; Cunningham, Clifford; page 45-46;
40. *Is Pluto a Planet? A Historical Journey through the Solar System;* **David A. Weintraub; page 99-100;** Is Pluto a planet? : a historical journey through the solar system : Weintraub, David A. (David Andrew), 1958- : Free Download, Borrow, and Streaming : Internet Archive;
41. Early Investigations of Ceres and the Discovery of Pallas: Historical Studies in Asteroid Research | SpringerLink; Cunningham, Clifford; page 115;
42. Early Investigations of Ceres and the Discovery of Pallas: Historical Studies in Asteroid Research | SpringerLink; Cunningham, Clifford; page 102-103;
43. GreatPlanetDebate.ppt (jhuapl.edu); Wayback Machine (archive.org)
44. Early Investigations of Ceres and the Discovery of Pallas: Historical Studies in Asteroid Research | SpringerLink; Cunningham, Clifford; page 49;
45. Studies of Pallas in the Early Nineteenth Century: Historical Studies in Asteroid Research | SpringerLink; Cunningham, Clifford; page 5 and 132;
46. Britannica, The Editors of Encyclopaedia. "ecliptic". Encyclopedia Britannica, 15 May. 2023, https://www.britannica.com/science/ecliptic. Accessed 28 August 2023.
47. Early Investigations of Ceres and the Discovery of Pallas: Historical Studies in Asteroid Research | SpringerLink; Cunningham, Clifford; page 49-58;
48. Asteroids, Cunningham (uchicago.edu); Cunningham, Clifford; page 22-24;
49. (PDF) Olbers's Planetary Explosion Hypothesis: Genesis and Early Nineteenth-Century Interpretations (researchgate.net); May 2013; Journal for the History of Astronomy; 44(2):187-206; DOI:10.1177/002182861304400205; CLIFFORD J. CUNNINGHAM and WAYNE ORCHISTON;
50. *Is Pluto a Planet? A Historical Journey through the Solar System;* **David A. Weintraub; page 102;** Is Pluto a planet? : a historical journey through the solar system : Weintraub, David A. (David Andrew), 1958- : Free Download, Borrow, and Streaming : Internet Archive;
51. GreatPlanetDebate.ppt (jhuapl.edu); Wayback Machine (archive.org);
52. Investigating the Origin of the Asteroids and Early Findings on Vesta: Historical Studies in Asteroid Research | SpringerLink; Cunningham, Clifford; page 87;
53. Bode's Law and the Discovery of Juno: Historical Studies in Asteroid Research | SpringerLink; Cunningham, Clifford; page 37;

54. What Is a Planet? -- [ASTROPHYSICS]: Scientific American (archive.org); The controversial new official definition of "planet," which banished Pluto, has its flaws but by and large captures essential scientific principles By Steven Soter
55. Dawn Community (archive.org); Flashbacks; No asteroid discoveries were reported between 1807 and 1845;
56. Miner, Ellis D.. "Neptune". Encyclopedia Britannica, 23 Aug. 2023, https://www.britannica.com/place/Neptune-planet. Accessed 29 August 2023.
57. Britannica, The Editors of Encyclopaedia. "Alexis Bouvard". Encyclopedia Britannica, 23 Jun. 2023, https://www.britannica.com/biography/Alexis-Bouvard. Accessed 29 August 2023.
58. Account of some circumstances historically connected with the discovery of the Planet exterior to Uranus. | Zenodo; G. B. Airy; First published: 1847; https://doi.org/10.1002/asna.18470251002;
59. The Neptune File: A Story of Astronomical Rivalry and the Pioneers of Planet Hunting | Request PDF (researchgate.net); March 2002; Isis 93(1):130-131; DOI:10.1086/343304; Michael Crowe; page 124;
60. The Hunt for Planet X: New Worlds and the Fate of Pluto | SpringerLink; Govert Schilling; page 24
61. Home page of Prof David N. Jamieson: University of Melbourne (unimelb.edu.au); Home page of Prof David N. Jamieson: University of Melbourne (archive.org); GalileoMay-June09.indd (unimelb.edu.au); Wayback Machine (archive.org);
62. In Search of Planet Vulcan: The Ghost in Newton's Clockwork Universe | SpringerLink; Richard Baum , William Sheehan; page 121;
63. The Search for a Planet beyond Neptune on JSTOR; Grosser, Morton; *Isis* 55, no. 2 (1964): 163–83.
64. Life on Mars : Paul Chambers : Free Download, Borrow, and Streaming : Internet Archive; page 34;
65. Britannica, The Editors of Encyclopaedia. "Percival Lowell". Encyclopedia Britannica, 8 Nov. 2022, https://www.britannica.com/biography/Percival-Lowell. Accessed 13 December 2022.
66. Agassiz, G.R. (1917). "Percival Lowell (1855-1916)" (PDF). *Proceedings of the American Academy of Arts and Sciences*. **52** (13): 845–847. JSTOR 20025724.
67. The Search for the Ninth Planet, Pluto - NASA/ADS (harvard.edu); Tombaugh, Clyde W.; Astronomical Society of the Pacific Leaflets, Vol. 5, No. 209, p.73; **Bibliographic Code:** 1946ASPL....5...73T;
68. Planet quest : the epic discovery of alien solar systems : Croswell, Ken : Free Download, Borrow, and Streaming : Internet Archive; page 48-54;
69. The hunt for planet X : new worlds and the fate of Pluto : Schilling, Govert : Free Download, Borrow, and Streaming : Internet Archive; page 29-38;
70. Finding Pluto: the hunt for Planet X — Research @ Flinders; Kevin Orrman-Rossiter, Alice Gorman;
71. Owen, Tobias Chant. "Pluto". Encyclopedia Britannica, 8 Aug. 2023, https://www.britannica.com/place/Pluto-dwarf-planet. Accessed 30 August 2023.
72. The Discovery of Pluto - The Search Continues; The Discovery of Pluto - The Search Continues (archive.org);
73. NASA - Transcript: The Girl Who Named Pluto | NASA; NASA - Transcript: The Girl Who Named Pluto | NASA (archive.org);

74. The hunt for planet X : new worlds and the fate of Pluto : Schilling, Govert : Free Download, Borrow, and Streaming : Internet Archive; page 39-43;
75. Planet X: No Dynamical Evidence in the Optical Observations - NASA/ADS (harvard.edu); Standish, E. M.; Astronomical Journal v.105, p.2000; DOI: 10.1086/116575;
76. W. H. Pickering's Planetary Predictions and the Discovery of Pluto on JSTOR; Hoyt, William Graves; Isis, vol. 67, no. 4, 1976, pp. 551–64.
77. The Neptune file : a story of astronomical rivalry and the pioneers of planet hunting : Standage, Tom : Free Download, Borrow, and Streaming : Internet Archive; page 188;
78. Davis, Phil; Dunford, Bill; Boeck, Moore. "Dawn: Between Jupiter and Mars [sic], I Place a Planet" (PDF). *Jet Propulsion Laboratory*. NASA. Archived (PDF) from the original on November 21, 2005.
79. Kavelaars, J.J. and Delsemme, Armand H.. "Kuiper belt". Encyclopedia Britannica, 23 Aug. 2023, https://www.britannica.com/place/Kuiper-belt. Accessed 30 August 2023.
80. What is the asteroid belt? | Cool Cosmos (caltech.edu); What is the asteroid belt? | Cool Cosmos (archive.org);
81. Chapman, Clark R.. "Eris". Encyclopedia Britannica, 16 Mar. 2023, https://www.britannica.com/place/Eris-astronomy. Accessed 30 August 2023.
82. A Short History of Pluto, the un-Planet (archive.org); Dr. Tony Phillips and Amelia Phillips, Sept. 4, 2006;
83. [2110.15285] Moons Are Planets: Scientific Usefulness Versus Cultural Teleology in the Taxonomy of Planetary Science (arxiv.org); Philip T. Metzger, William M. Grundy, Mark Sykes, S. Alan Stern, James F. Bell III, Charlene E. Detelich, Kirby D. Runyon, Michael Summers; The IAU's, 2006 vote on a definition of Planet;
84. Wayback Machine (archive.org); The Mass of Dwarf Planet Eris Michael E. Brown* and Emily L. Schaller;
85. New Planet (caltech.edu); New Planet (archive.org); The discovery of ~~2003 UB313~~ Eris, the ~~10th planet~~ largest known dwarf planet;
86. StarChild: The Dwarf Planet Eris (nasa.gov); StarChild: The Dwarf Planet Eris (archive.org);
87. Mercury: The View after MESSENGER – LPIB (usra.edu); Solomon, Sean C. · Nittler, Larry R. · Anderson, Brian J.; DOI: 10.1017/9781316650684; Bibcode: 2018mvam.book.....S; page 73;
88. Generalized Titius-Bode Law and How to Statistically Verify it - NASA/ADS (harvard.edu); Hu, Wei; Journal of Physics: Conference Series, Volume 1865, Issue 4, article id. 042109 (2021).; DOI: 10.1088/1742-6596/1865/4/042109;
89. (PDF) On the Structural law of Exoplanetary Systems (researchgate.net); P. Lara†, A. Poveda and C. Allen; DOI:10.1063/1.4756667;
90. Bode's Law, a suggested substitute for - NASA/ADS (harvard.edu); Blagg, M. A.; Monthly Notices of the Royal Astronomical Society, Vol. 73, p.414; DOI: 10.1093/mnras/73.6.414;
91. (PDF) Applying Titius-Bode's Law on Exoplanetry Systems (researchgate.net); M. B. Altaie, Zahraa Yousef, A. I. Al-Sharif;
92. Conclusions about the Titius Bode Law of Planetary Distances - NASA/ADS (harvard.edu); Nieto, M. M.; Astronomy and Astrophysics, Vol. 8, p. 105 (1970);

93. A Tale of Two Laws—Bode's Law and Kepler's Law | SpringerLink; Kossovsky, A.E. (2020); https://doi.org/10.1007/978-3-030-51744-1_46
94. The Generalized Bode's Law, viXra.org e-Print archive, viXra:1510.0067; Rodolfo A. Frino;
95. In Search of Planet Vulcan: The Ghost in Newton's Clockwork Universe | SpringerLink; Richard Baum , William Sheehan; page 133-156, 265, 164 and chapter 11;
96. Wayback Machine (archive.org); Mercury's Perihelion Chris Pollock March 31, 2003;
97. In Search of Planet Vulcan: The Ghost in Newton's Clockwork Universe | SpringerLink; Richard Baum , William Sheehan; page 236, 241-242 and 266;
98. Le monde merveilleux d'Edmond Lescarbault | ECHOSCIENCES - Centre-Val de Loire

Ashes to Ashes, Dust to Dust

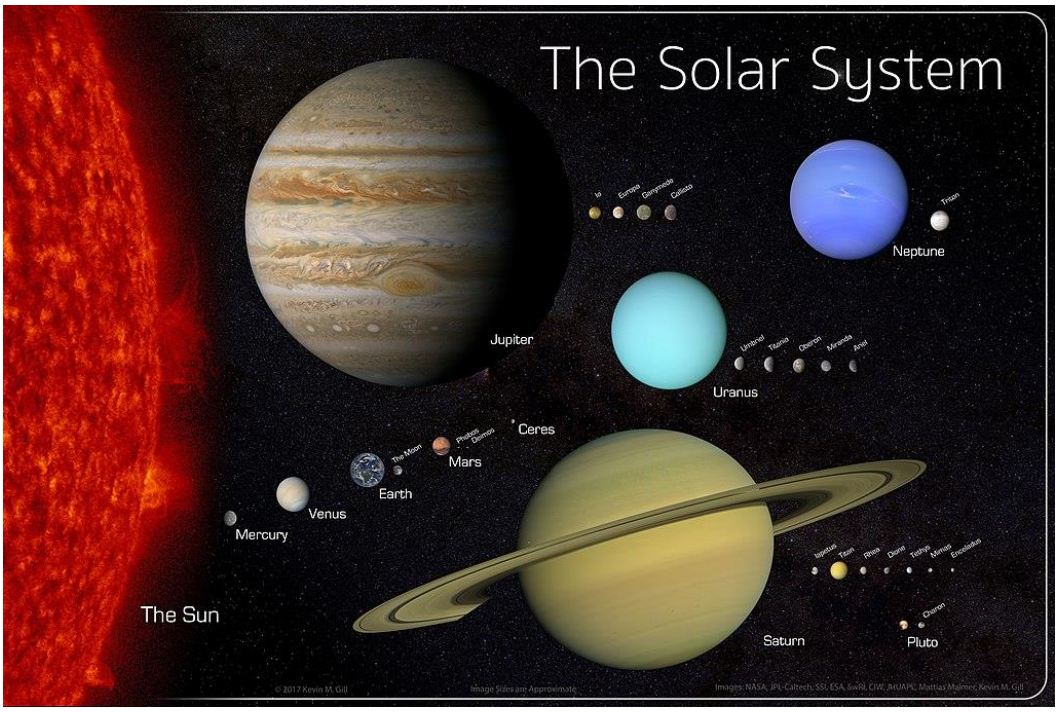


Figure 1: Some members of our solar system

What is the story behind the formation of our solar system? Although there are various hypotheses, the most famous one is called the nebular hypothesis. [1] [2]

Molecular clouds are the very places where stars are born, thus they are also referred to as stellar nurseries. Despite taking up a small fraction of space in terms of volume, they contain 20-30 percent of the total mass of the gases present in the Milky Way. The reason is plane and direct, molecular clouds have higher density. Our universe is not completely empty, but rather filled with dust and gas particles. Molecular clouds are places where the gas and dust exist in a higher density. This high density prevents ultraviolet light from penetrating the molecular clouds. Ultraviolet light can break molecules (a group of atoms) into atoms. Therefore, while atoms are commonly found in other parts of space, molecules can form inside molecular clouds. [3] [4] [5] (That is, molecular clouds are like parks that are enclosed by a wall, so that you can't see inside from outside. In such parks you will find many couples roaming around, hand in hand since no one can see them from outside. But when they go outside, they feel embarrassed for they get visible to all and break up. Molecules are similar. When ultraviolet light hits them, they feel shy and ditches their companions' hands.)

When the mass of these clouds reaches an enormous amount, the gas starts to clump together at a single point due to the gravitational pull. And at some point, this lump eventually turns into a star. However, the molecular clouds must have a significantly larger mass for clump to form. The cloud that our sun was formed from did not have that much mass. If there isn't enough mass, it needs a trigger to begin this process. When a massive star dies, it causes an explosion called a supernova. In a supernova, a shock wave spreads around it. If this shock wave can cause

a bit of stir in a molecular cloud, then its gases begin to accumulate together triggered by that stir. In addition to supernovae, collisions of molecular clouds or collisions of galaxies can also do the job.

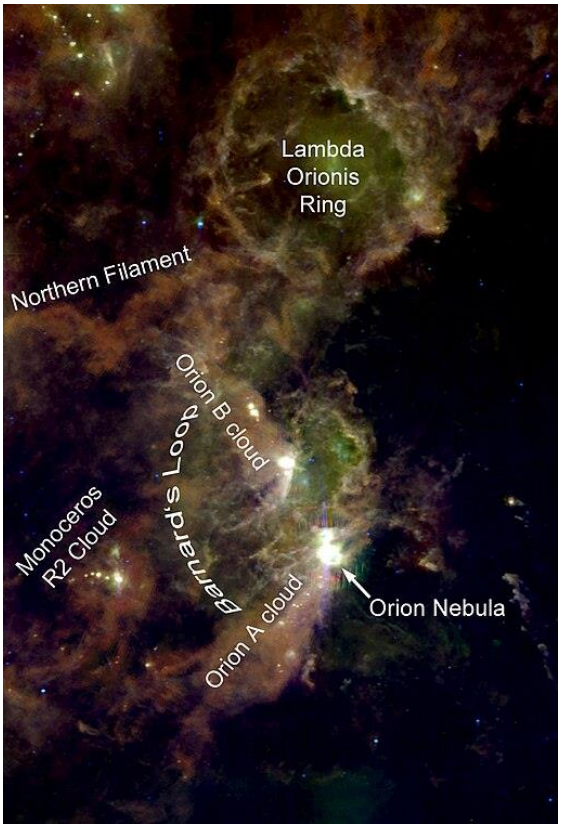


Figure 2: Orion molecular cloud

The pressure is not the same everywhere throughout these clouds. As a result, the gases that are in between tend to move in different directions which is called turbulence. When the gases accumulate to form a lump, this turbulence causes the lump to spin, quite slowly at first. The lump gradually shrinks due to the gravitational pull, and consequently, its spinning speed also increases, little by little. [6] [7] [8] [9]

But this increase in rotational speed doesn't happen by itself. Have you ever noticed that the small ceiling fans in the shops seem to spin at the speed of a Chita while the ceiling fans hanging from your own roof do not seem to want to spin at all? The trick is that, with the same amount of force, small objects spin faster than large ones. This same thing happens with our gas lump. The smaller the lump gets, the faster it spins.

Once, three thieves were caught in a village. The villagers caught them after a lot of running and chasing. One was a cow thief, another was a goat thief, and the third used to steal chicken. The hardest one to catch was the chicken thief while the cow thief was caught most easily. When the villagers called the police, they were told that the police were coming; the thieves should be tied up until they arrive. So, the mass tied them up. Then, somehow, it occurred to them that, if they handed the thieves over to the police, they would receive punishment only for the stolen items. However, the villagers had to run miles after miles to catch the thieves, so what punishment would they receive for making the villagers chase after them for miles on end? On the other hand, after so much running and chasing, the villagers had no strength left to beat up the thieves. So, they hit upon a plan. They placed a bamboo pool on the lawn of a house. Then they tied one end of a ten-meter rope to the pole and the other end to the chicken thief's leg. The same rope was tied to the goat thief five meters away from the pole and to the cow thief two meters away from the pole. The chicken thief was then told to run at ten meters per second and a dog was released behind him, for if he slows down, it would munch on his bones. Since they were tied to the same rope, if the chicken thief ran, the goat thief and the cow thief would have to run too. One might ask, how was justice done here? As it was harder to catch the chicken thief, he should run more than the others as a punishment.

Upon reflection, it becomes apparent that justice was served here. Because they were tied to the same rope, the chicken thief would cover one lap in the same time as the goat thief and the cow thief. But because he was farther away from the bamboo pole than them, he would have to cover more distance than them in one lap. As a result, the goat thief and the cow thief would be able to complete one lap in the same time as the chicken thief if they ran slowly. And when the police came, the villagers would say that the thieves were tied up all this time! Everybody wins.

Oh! Something I forgot to mention, the house where the thieves were running belonged to a mountaineer. (Actually, I didn't really forget. But I see many people writing in this way, so I thought why not try it?) But that mountaineer is afraid of heights. And he is very lazy too. So he has raised the circular courtyard of his house shaped like half of a football. Taller in the middle, and sloped downward as you increase your distance from the midpoint. The bamboo pool to which the thieves were tied to was placed in the highest spot, that is, the midpoint. As a result, the cow thief was near the top of the football. And the chicken thief was near the ground, or in comparison with the football, in the middle position. In posh English, on the equator of the football. Even then, the chicken thief would have to cover more distance than the others. Everything was going well, but after a few moments it was seen that the goat thief had fallen for some reason and was strangely swaying his head downward while his legs were pointing upwards. Actually, the villagers' plan was quite good, but they had forgotten that running around in such a small space might make someone dizzy! Now, now, what can be the excuse when the police arrive?

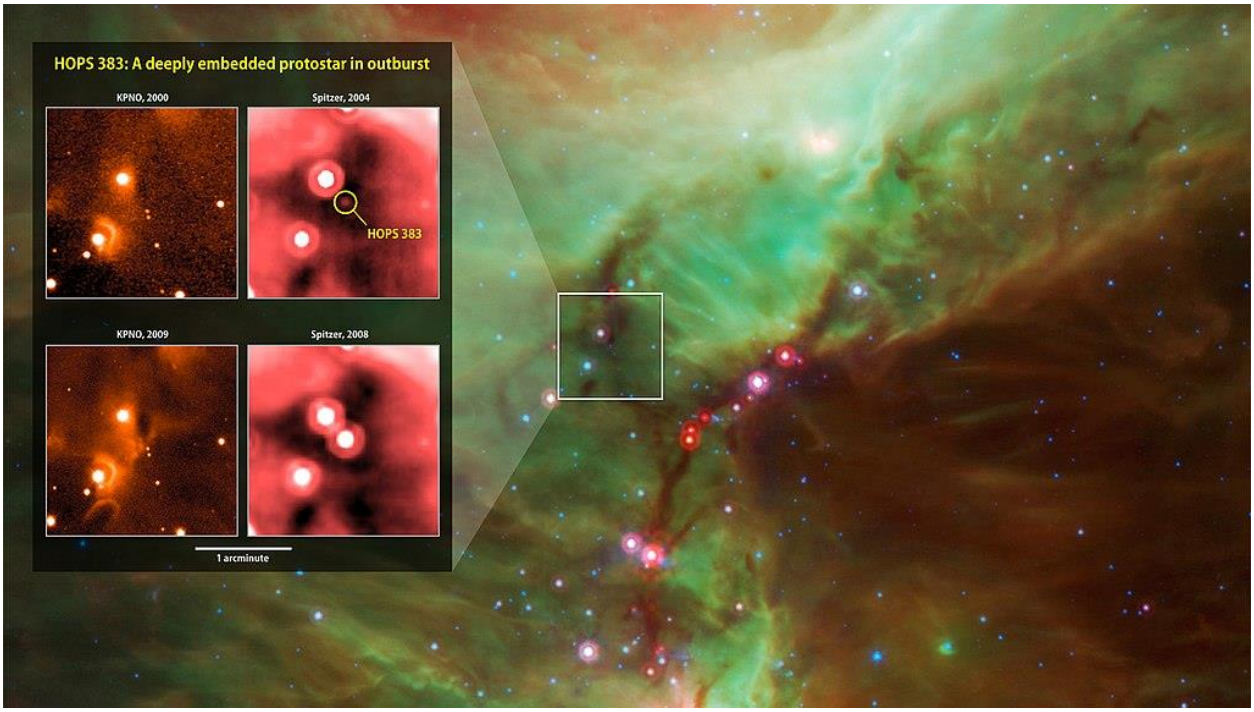


Figure 3: HOPS 383, on its way to form a star

Something similar happens to our lump of gas. The molecular cloud gases that are in the middle (equator to be precise) of the lump have a higher velocity, so they do not want to compress easily. Conversely, the

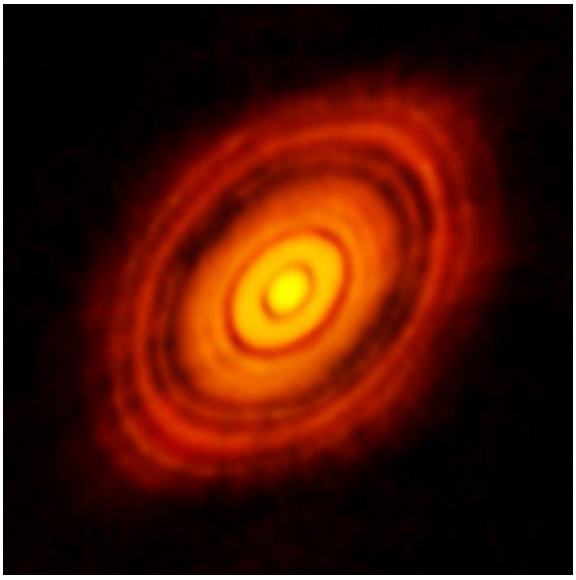


Figure 4: Young star, HL Tauri with its disk; This image was taken by ALMA

gases that are above and below have an easier time shrinking. This is similar to a stone tied to a rope and spun horizontally to the ground; as long as it keeps moving, the stone will not fall down. It starts falling towards the ground only when the rope's movement slows down or stops. Whatever, the result is a disk-shaped structure around the lump. [8]

The more the lump of gas contracts, the higher its temperature rises. At some point the temperature rises so high that the lump can no longer shrink, and at some point, it forms a star. After a certain point in the process of star formation, gas starts to escape from it at high speed. This gas emission is called stellar wind. This stellar wind sweeps away the excess dust around the star (the excess of the molecular cloud) and leaving the nacked star and the disk around it as the only garment. As time goes on, the disk slowly transforms into planets. And since the planets originate from a disk, they also orbit the sun like a disk does. Consequently, it appears from earth that all the planets are located within 8 degrees of the ecliptic. But some small objects, such as Pallas or Pluto, deviate from their orbits due to the pull of various heavy objects (such as Jupiter) and exceeds the ecliptic. [10] [11] [12] [13]

Due to the extreme heat, no gas or ice could accumulate near the sun. Therefore, planets like Mercury to Mars are primarily formed from solid or rocky materials. Thus, they are called rocky planets. Jupiter and Saturn, on the other hand, are gas giants since they are made up of gas. Uranus and Neptune, which formed farther from the sun, are ice giants as they are made up of mostly ice. [1]

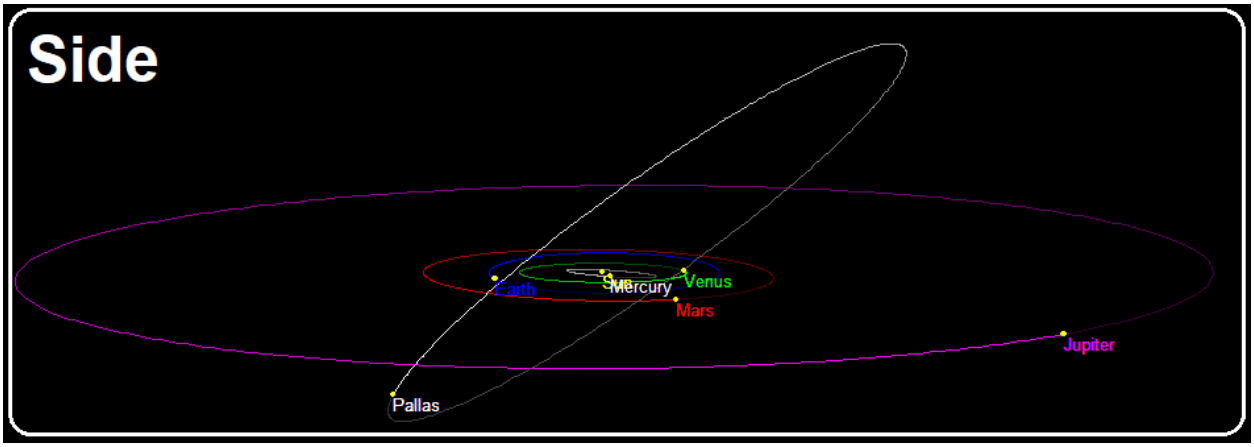


Figure 5: This image is showing how oblique Pallas' orbit is

In many cases, not one, but two or three stars can be formed. In such cases, the stars revolve around their mutual centre of mass. If there are two stars, they are called a binary star system. In fact, in our Milkyway, there are numerous binary star systems, probably almost half of the

star systems are binary. Our closest neighbour, Alpha Centauri, is a triple star system, which means three stars revolve around a centre of mass there. What if our solar system was like this?

Figure 6: The closest star system to us is Alpha Centauri; it's made up of the two brightest stars and a relatively small star in the middle of that red circle; however, by closest, we mean, 37.8 trillion kilometers, or 37,800,000, 000,000 kilometers.

1. Owen, Tobias Chant. "solar system". Encyclopedia Britannica, 10 Sep. 2023, https://www.britannica.com/science/solar-system. Accessed 11 September 2023.
2. *Woolfson, M.M. (1993). "Solar System – its origin and evolution". Q. J. R. Astron. Soc.* ***34****: 1–20.* Bibcode:1993QJRAS..34....1W. For details of Kant's position, see Stephen Palmquist, "Kant's Cosmogony Re-Evaluated", *Studies in History and Philosophy of Science* 18:3 (September 1987), pp.255–269.
3. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-951693-50-3; page 729;
4. Mathis, John S.. "molecular cloud". Encyclopedia Britannica, 8 May. 2020, https://www.britannica.com/science/molecular-cloud. Accessed 11 September 2023.
5. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-951693-50-3; page 701-703;
6. Prialnik, Dina (2000). *An Introduction to the Theory of Stellar Structure and Evolution*. Cambridge University Press. 195–212. ISBN 0-521-65065-8.
7. Lecture 35: When Galaxies Collide! (ohio-state.edu); Lecture 35: When Galaxies Collide! (archive.org);
8. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-951693-50-3; page 1036 and 732-734;
9. Williams, J. (2010). "The astrophysical environment of the solar birthplace". *Contemporary Physics*. **51** (5): 381–396. arXiv:1008.2973. Bibcode:2010ConPh..51..381W. doi:10.1080/00107511003764725. S2CID 118354201.
10. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-951693-50-3; page 736 and 739-743;
11. The Plane of the Ecliptic | NASA; The Plane of the Ecliptic | NASA (archive.org);
12. The origin of Pluto's peculiar orbit | Nature; Malhotra, R. The origin of Pluto's peculiar orbit. Nature 365, 819–821 (1993). https://doi.org/10.1038/365819a0;
13. [1811.07916] Excitation and depletion of the asteroid belt in the early instability scenario (arxiv.org); Matthew S. Clement, Sean N. Raymond, Nathan A. Kaib; https://doi.org/10.48550/arXiv.1811.07916; Excitation and Depletion of the Asteroid Belt in the Early Instability Scenario - NASA/ADS (harvard.edu);
14. Britannica, The Editors of Encyclopaedia. "binary star". Encyclopedia Britannica, 5 Sep. 2019, https://www.britannica.com/science/binary-star. Accessed 12 September 2023.
15. Introduction to Binary Stars (csiro.au); Introduction to Binary Stars (archive.org);
16. Multiple Star Systems | Stars – NASA Universe Exploration; Multiple Star Systems | Stars – NASA Universe Exploration (archive.org);
17. [1405.7105] The binarity of Milky Way F,G,K stars as a function of effective temperature and metallicity (arxiv.org); Shuang Gao, Chao Liu, Xiaobin Zhang, Stephen Justham, Licai Deng, Ming Yang; https://doi.org/10.48550/arXiv.1405.7105; The Binarity of Milky Way F,G,K Stars as a Function of Effective Temperature and Metallicity - NASA/ADS (harvard.edu)
18. Britannica, The Editors of Encyclopaedia. "Alpha Centauri". Encyclopedia Britannica, 9 Sep. 2023, https://www.britannica.com/place/Alpha-Centauri. Accessed 12 September 2023.

Milky Threads

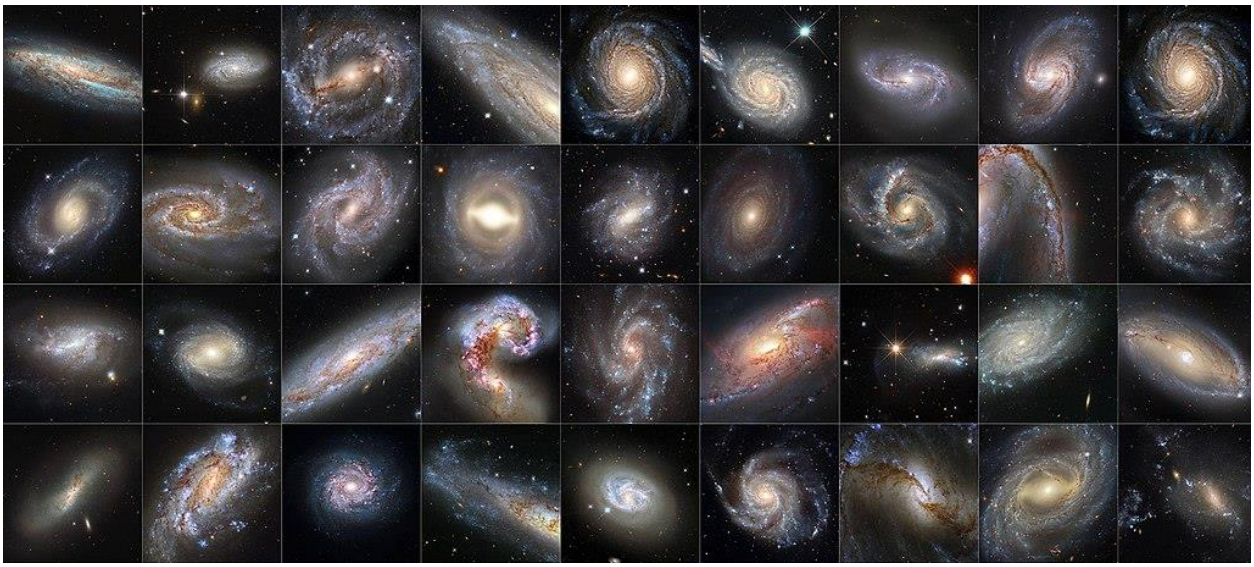


Figure 1: A Collage of some galaxies; all these images were taken by Hubble Space Telescope

To put it simply, a galaxy, is a complex collection of several star systems, gas, dust particles, etc. Due to the force of gravity, these stars, gas, and dust clusters together inside different galaxies. [6] Their sizes, unimaginable, measuring about 3,000-700,000 light-years in diameter. [5] Some of these giant-sized galaxies (Since giants and monsters are supposed to live on Earth, they should be smaller than the planet. Therefore, comparing them with galaxies was not appropriate. However, I will still call them gigantic! Why? That's my secret, and it can't be revealed! Ha ha ha ha ha, it's so much fun to annoy people!) form clusters by joining together with gravitational force. These clusters, in turn, form superclusters due to the influence of gravity. Our Milky Way is a member of one such supercluster. Can you imagine what might be the length of this supercluster? 500 million light-years. If you put the zeros, 50,00,00,000 light-years. [7] [8] And converted to meters… Anyway, let's not get any deeper than this, we'll just return to galaxies. [1] [2] [3] [4]

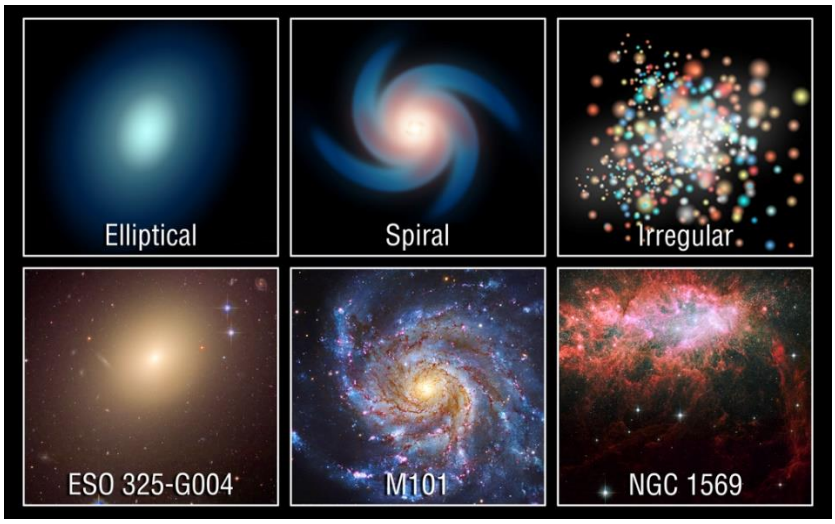


Figure 2: Different types of galaxies

By appearance, galaxies are usually elliptical, spiral and irregular in shape. [9] Some galaxies are called dwarf galaxies, meaning they are quite small in size. However, the funny thing is that most galaxies in the universe are actually dwarf galaxies. [10] [11] [14]

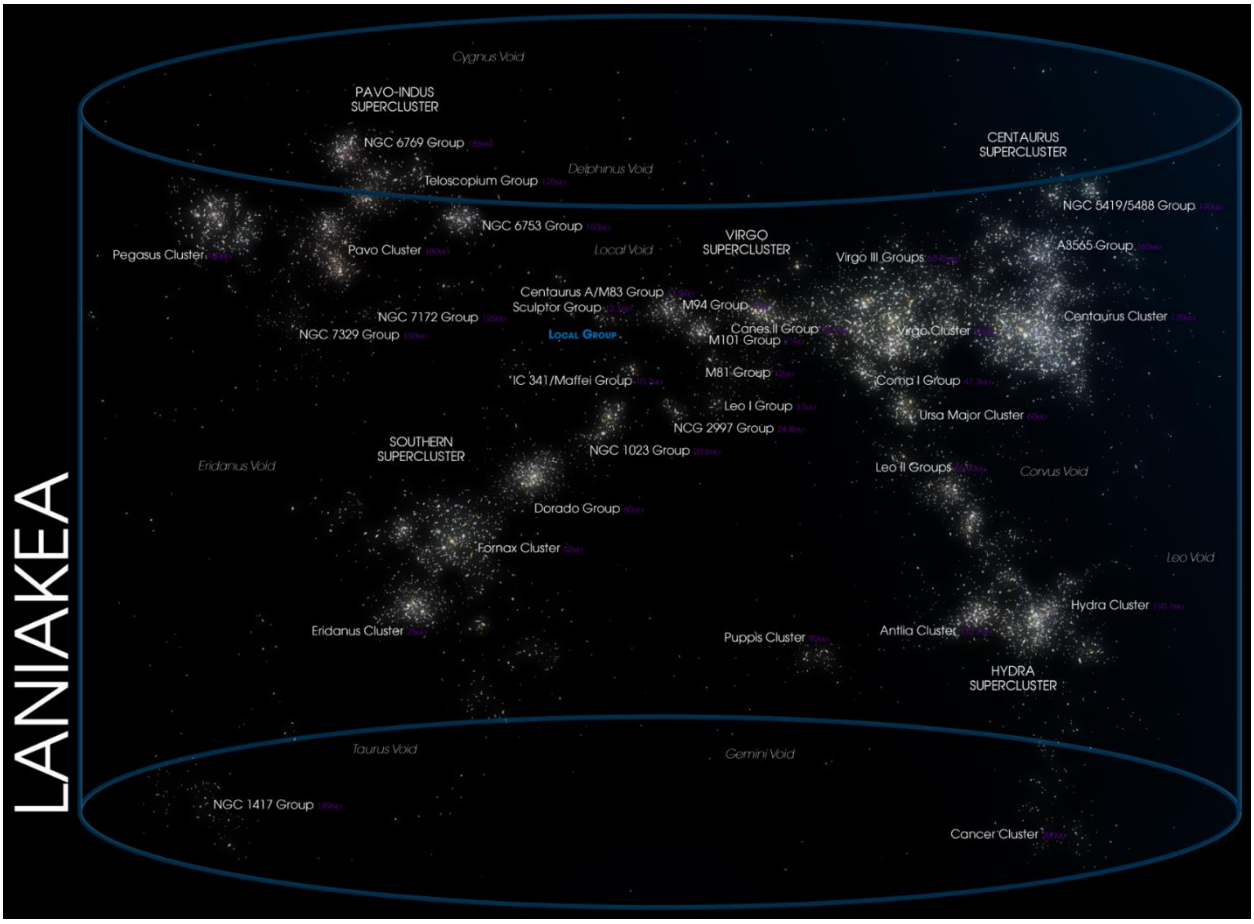


Figure 3: The Local Group Cluster of Laniakea Super Cluster contains our galaxy, Milky way; to have a better view, visit the link

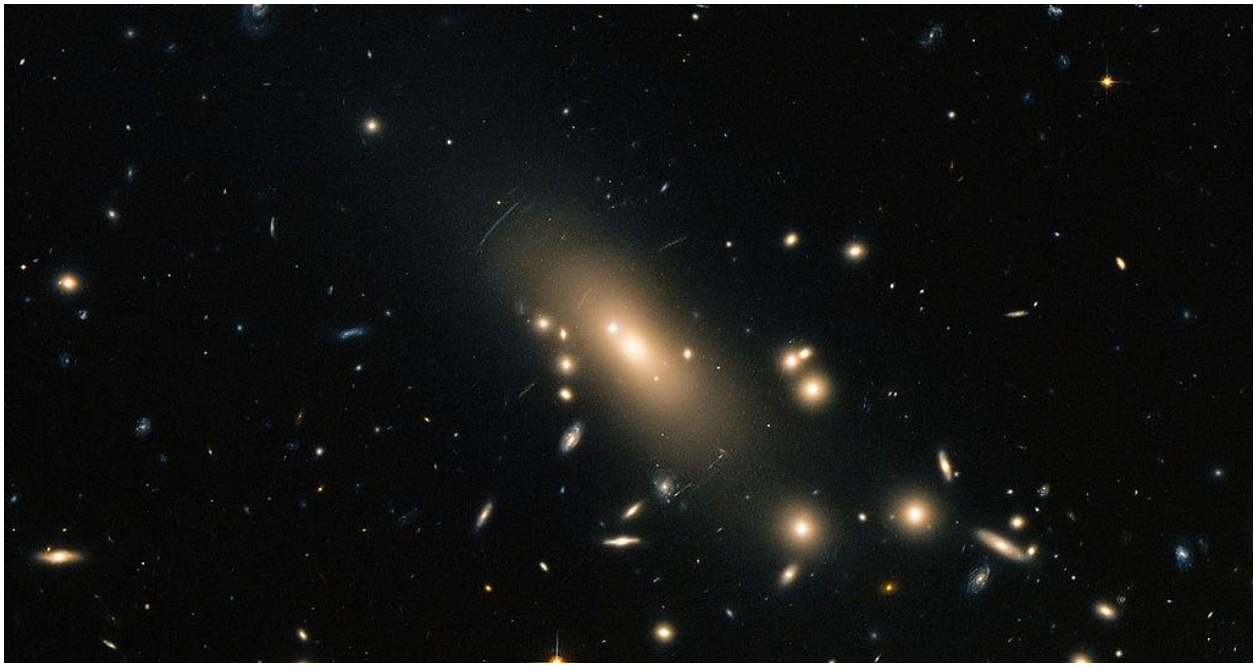


Figure 4: Cluster, Abell 1413 from Hubble Space Telescope

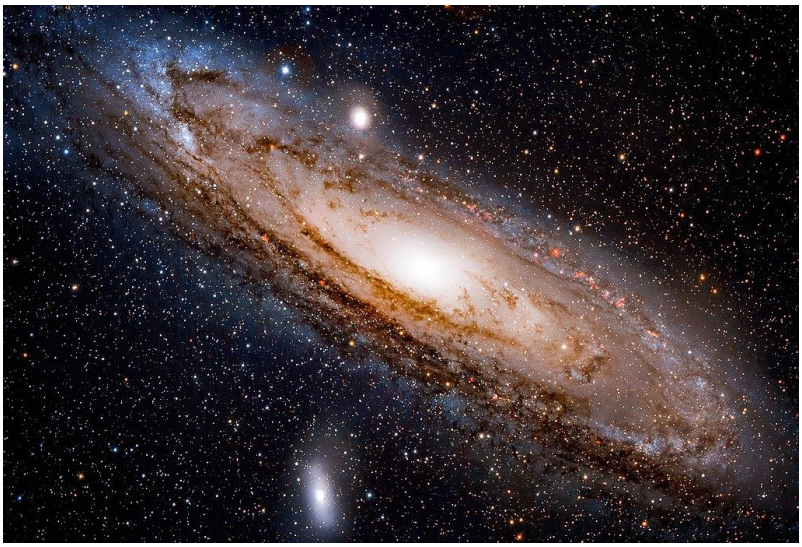


Figure 5: The closest major galaxy to the Milky Way, Andromeda and its satellite galaxy; Andromeda is an example of a spiral galaxy.

More interestingly, just as the planets orbit the sun, or the sun orbits the center of the Milky Way, some dwarf galaxies also orbit around larger galaxies. Those galaxies that orbit another galaxy are called satellite galaxies. [12] Our Milky Way has about a dozen of these satellite galaxies! [13]

Now the question arises: how were the galaxies formed? At the beginning of the universe, galaxies were formed by the accumulation of matter which were present that time (hydrogen, helium, etc.). However, what exactly happens when a galaxy is formed is a subject of research.

Galaxies are made up of hydrogen, helium, and other elements that formed after the Big Bang. According to the bottom-up model, galaxies are initially spiral-shaped and later some spiral galaxies transform into elliptical galaxies.

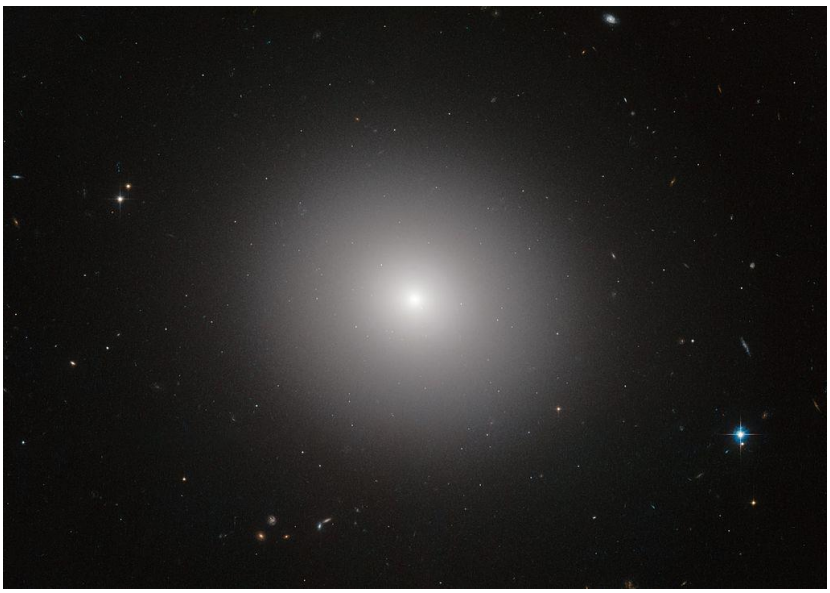


Figure 6: Elliptical Galaxy IC 2006 from the Hubble Space Telescope

The productivity rate of the new stars in these elliptical galaxies is relatively lower. (That is, it is understood that the more twisted one is, the more productive he would be) In addition, the stars in these type galaxies are relatively older, and their mass, lower.

About 60% of the galaxies in the universe are spiral galaxies. A spiral galaxy looks like a spiral. There is a center and there are several arms, which are called spiral arms. These arms contain more gas and stars compared to other parts of the galaxy. Spiral-shaped galaxies can again be divided into two distinct categories: barred and barless. Approximately two-thirds of the spiral galaxies in the universe are barred.

Figure 7: Irregular galaxy I Zwicky 18a from Hubble Space Telescope

In barred spiral galaxies, a central bar-shaped structure composed of stars is visible. The Milky Way, our own galaxy, is a barred spiral galaxy.

Our solar system is located on the outer edge of the Milky Way galaxy, at a considerable distance from the center. Once in every 240 million years the Sun completes its rotation around center of the galaxy. The center and arms of the galaxy are always unstable. The number of stars present towards the center of the galaxy is relatively higher, forming a dense, conglomerate structure, almost a cluster. If our solar system were located near the center of the galaxy, the gravitational pull of those stars would cause numerous objects to approach the Earth from different directions. And if such an object were to collide with the earth, just imagine what the consequences would be!

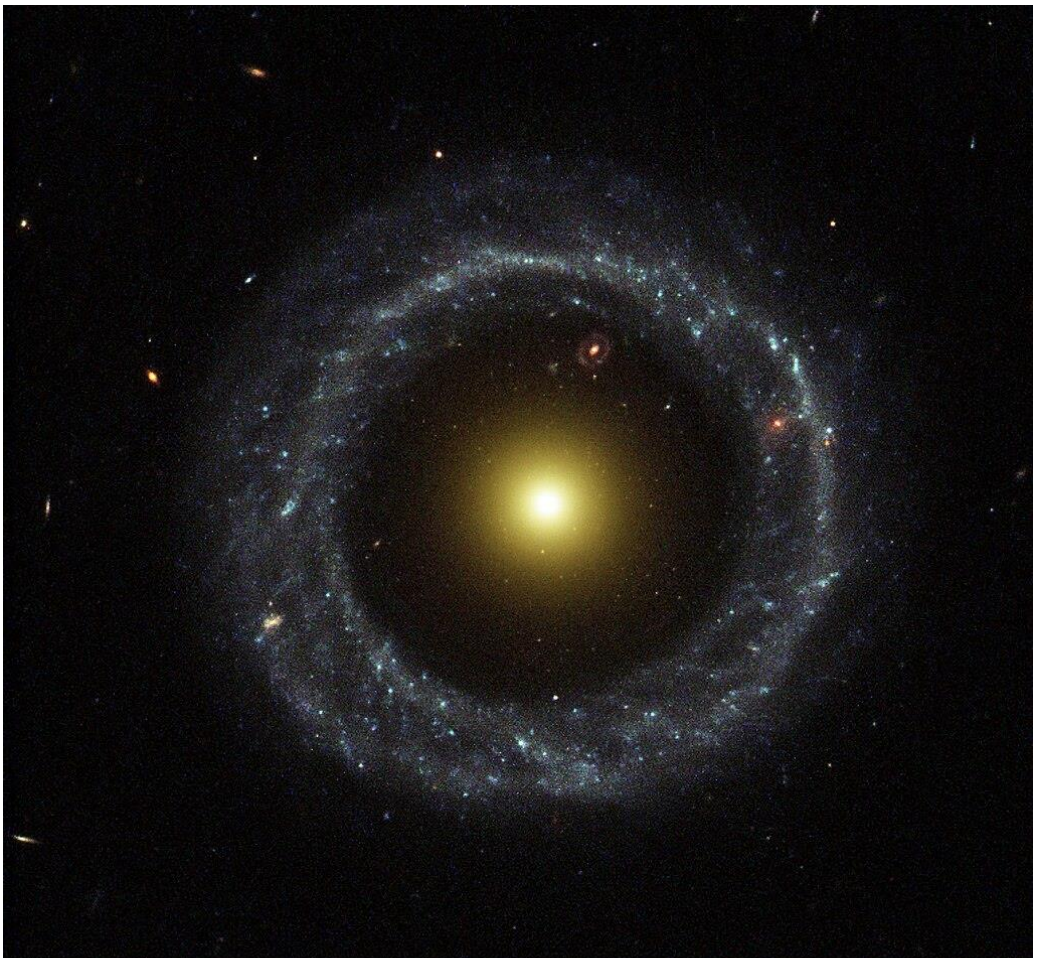


Figure 8: Ring galaxy, Hog's Object from Hubble Space Telescope

Figure 9: Sombrero galaxy from Hubble Space Telescope

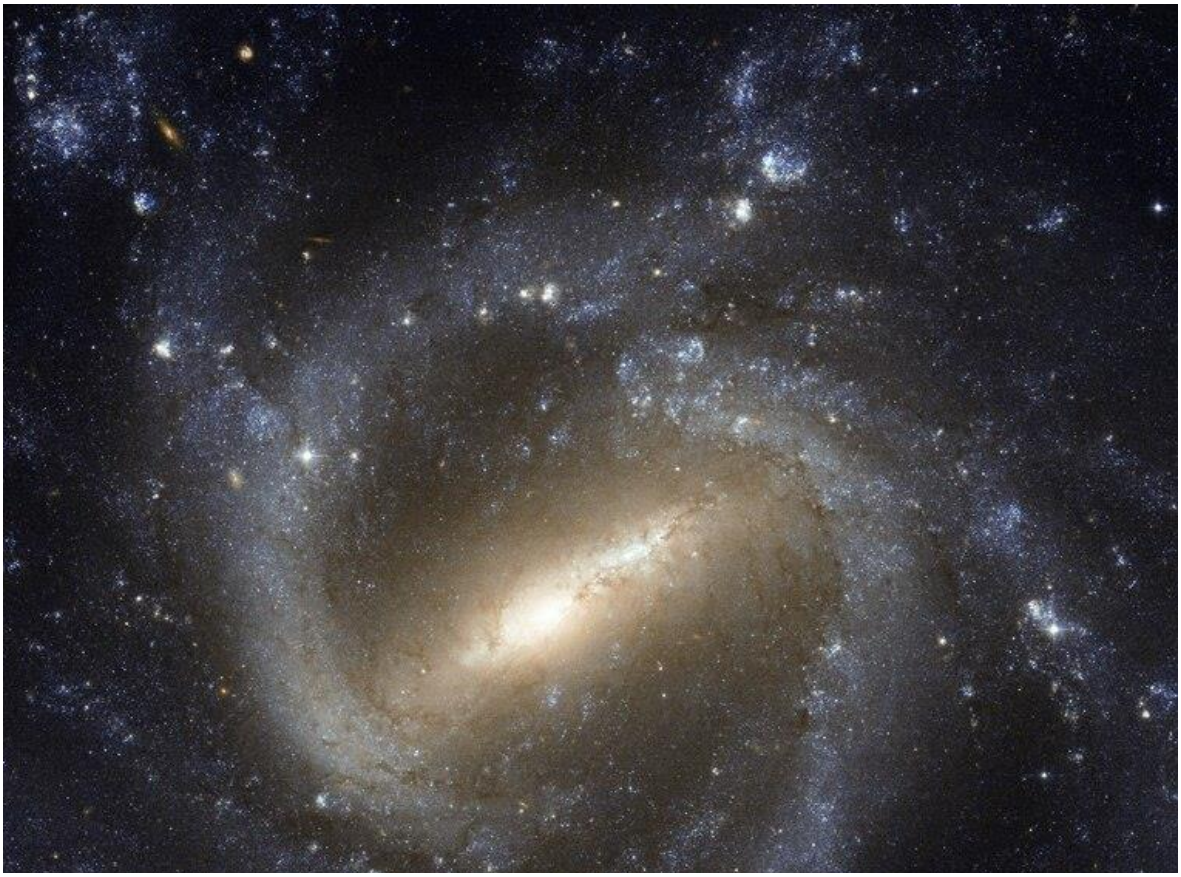


Figure 10: Barred spiral galaxy NGC 1073 from Hubble Space Telescope

Figure 11: Spiral galaxy NGC 1232 from the Danish telescope at ESO La Silla Observatory

Figure 12: Needle Galaxy, imaged by Shaihulud D. D.

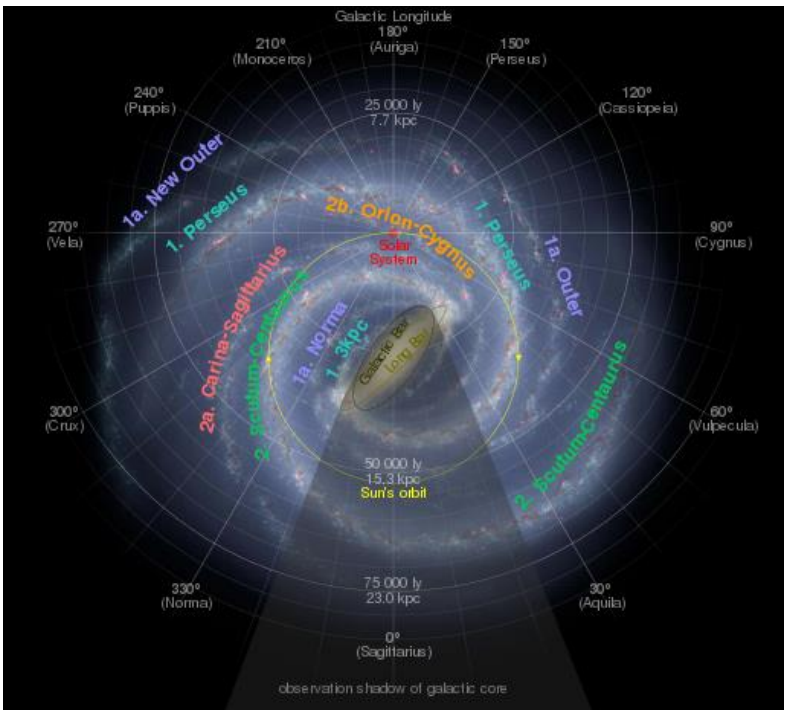


Figure 13: Position of Solar System in the Milky Way galaxy

Moreover, the radiation near the central region of the galaxy is much higher than other regions. In the sun's radiation, one has to go out in the noon covering the face and other body parts with a layer of sunscreen lotion, otherwise there is a fear of cancer. What would happen if the solar system were closer to the center of the galaxy?

Given the age of the solar system and the type of star the sun is, there is an unusually high amount of metal present in the solar system.

By mass, the most abundant element on Earth is iron, at about 32%. This metal is, however, very important for the existence of life on Earth. So where did all this metal come from? It is believed that our solar system was born not where it is now but in a region of the Milky Way galaxy where there were a lot of metal present. Overtime, it moved into its current location.

Again, while most of the stars have elliptical orbits, our sun's orbit is almost circular. And, the speed of the sun in its orbit is almost equal to the speed of the spiral arms. As a result, the sun rarely crosses the spiral arms in its lifetime. There are more stars, supernovas, gravitational instability, radiation in the spiral arms. If the sun's orbit were a little more elliptical (it is assumed that a circle is straight and an ellipse is a little crooked. That is, those who are straight are more productive. For example, as far as we know, life exists in only in our solar system. But if that is the case, then it would be contradictory to the previous theory. There, the spiral galaxies twisted as jalebis are more productive! No! I just don't know!) or, if the speed was a little more or less, it would lead to frequent passes through the spiral arms, this would, of course, make the solar system much more unstable. Would life be possible in such an unstable solar system? There are also some theories that suggests that the mass extinction events that have occurred on Earth, such as the extinction of dinosaurs, occurred when the sun crossed one of the spiral arms of the Milky Way. However, these theories are controversial.

Figure 14: A panoramic image of the Milky Way from the European Southern Observatory (ESO); we will never be able to take a complete picture of the Milky Way as long as we cannot venture outside of it; Voyager 1, launched in 1977, is the farthest human-made object so far, which only crossed the heliosphere in 2012. The fastest human-made object is the Parker Solar Probe, which has a speed of almost 69 kilometers per second, quite fast, right? Since the shape of the Milky Way is like a disc, its thickness is very low; where its diameter is about 90,000 light-years, its thickness is only 1,000 light-years; If you prefer this in kilometers, the figure is 9,460,730,472,580,800.

1. Hodge, Paul W.. "galaxy". Encyclopedia Britannica, 11 Sep. 2023, https://www.britannica.com/science/galaxy. Accessed 12 September 2023.
2. "Hubble Pinpoints Furthest Protocluster of Galaxies Ever Seen". *ESA/Hubble Press Release*. Retrieved 13 January 2012. Hubble pinpoints furthest protocluster of galaxies ever seen | ESA/Hubble (archive.org);
3. Britannica, The Editors of Encyclopaedia. "list of galaxies and galaxy clusters". Encyclopedia Britannica, 17 Feb. 2016, https://www.britannica.com/topic/list-of-galaxies-and-galaxy-clusters-2056030. Accessed 12 September 2023.
4. Shu, Frank H.. "supercluster". Encyclopedia Britannica, 27 Jan. 2015, https://www.britannica.com/science/supercluster. Accessed 12 September 2023.
5. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-951693-50-3; page 881;
6. What Is a Galaxy? | NASA Space Place – NASA Science for Kids; What Is a Galaxy? | NASA Space Place – NASA Science for Kids (archive.org);
7. Newly Identified Galactic Supercluster Is Home to the Milky Way - National Radio Astronomy Observatory (nrao.edu); Newly Identified Galactic Supercluster Is Home to the Milky Way - National Radio Astronomy Observatory (archive.org);
8. New Map Locates Milky Way in Neighborhood of 100,000 Galaxies (nationalgeographic.com); New Map Locates Milky Way in Neighborhood of 100,000 Galaxies (archive.org);
9. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-951693-50-3; page 875-880;
10. Dwarf galaxies (nature.com); Dwarf galaxies (archive.org);
11. Dwarf Galaxy | ESA/Hubble | ESA/Hubble (esahubble.org); Dwarf Galaxy | ESA/Hubble | ESA/Hubble (archive.org);
12. What Is a Satellite Galaxy? | NASA Space Place – NASA Science for Kids; What Is a Satellite Galaxy? | NASA Space Place – NASA Science for Kids (archive.org);
13. A. Drlica-Wagner (2020). "The Astrophysical Journal | Milky Way Satellite Census. I. The Observational Selection Function for Milky Way Satellites in DES Y3 and Pan-STARRS DR1". *The Astrophysical Journal*. **893** (1): 47. doi:10.3847/1538-4357/ab7eb9. hdl:10150/642363. S2CID 208857848.
14. Dwarf Galaxy | COSMOS (swin.edu.au); Dwarf Galaxy | COSMOS (archive.org);
15. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-951693-50-3; page 962-964;
16. NASA SVS | Galaxy Formation; NASA SVS | Galaxy Formation | Ghostarchive;
17. Evolution | Galaxies – NASA Universe Exploration; Evolution | Galaxies – NASA Universe Exploration (archive.org);
18. Spiral Galaxy Formation | COSMOS (swin.edu.au); Spiral Galaxy Formation | COSMOS (archive.org);
19. Evolution Of Galaxies | COSMOS (swin.edu.au); Evolution Of Galaxies | COSMOS (archive.org);
20. Types | Galaxies – NASA Universe Exploration; Types | Galaxies – NASA Universe Exploration (archive.org);
21. Elliptical Galaxy | ESA/Hubble | ESA/Hubble (esahubble.org); Elliptical Galaxy | ESA/Hubble | ESA/Hubble (archive.org);
22. Spiral Galaxy | ESA/Hubble | ESA/Hubble (esahubble.org); Spiral Galaxy | ESA/Hubble | ESA/Hubble (archive.org);
23. Galaxy Types | COSMOS (swin.edu.au); Galaxy Types | COSMOS (archive.org);
24. Hubble Snaps Stunning Barred Spiral Galaxy | NASA; Hubble Snaps Stunning Barred Spiral Galaxy | NASA (archive.org);

25. Mullen, Leslie (18 May 2001). "Galactic Habitable Zones". *Astrobiology Magazine*. Archived from the original on 7 August 2011. Retrieved 1 June 2020.
26. Bailer-Jones, C. A. L. (1 July 2009). "The evidence for and against astronomical impacts on climate change and mass extinctions: a review". *International Journal of Astrobiology*. **8** (3): 213–219. arXiv:0905.3919. Bibcode:2009IJAsB...8..213B. doi:10.1017/S147355040999005X. S2CID 2028999. Archived from the original on 1 April 2022. Retrieved 1 April 2022.
27. Morgan, J. W.; Anders, E. (1980). "Chemical composition of Earth, Venus, and Mercury". *Proceedings of the National Academy of Sciences*. **77** (12): 6973–6977. Bibcode:1980PNAS...77.6973M. doi:10.1073/pnas.77.12.6973. PMC 350422. PMID 16592930.

Helios and 26-Year-Old Helium

Figure 1: Osprey flying towards the horizon and the setting sun of the evening

About ninety-nine percent of the total mass of our solar system is occupied by the Sun. The Sun is a medium-sized star, but it is among the top five percent of nearby stars in size. The age is about 4.5 billion years. Its distance from Earth is 150 million kilometers. And the temperature at the center is 15 million degrees Celsius, and the pressure is six times that of the Earth's center while its volume is equal to 1.3 million Earths. Its mass is 73% hydrogen and 25% helium. There are also traces of oxygen, carbon, neon, iron, etc. Cecilia Payne-Gaposchkin showed in 1925 that hydrogen and helium are the most abundant elements in the Sun. But it was very unexpected at that time that the Sun was made of light gases like hydrogen and helium. Even Gaposchkin herself said, "The abundance of these elements in the solar atmosphere is probably not real." [1] [2] [3]

The Sun has no solid surface. What we see from earth as the surface of the Sun is called the photosphere. The solar atmosphere is transparent, but as the distance increases, the visibility limit decreases. The photosphere is the layer of the Sun where the visibility limit becomes zero. We can't see what's inside the photosphere. So, it is called the surface of the Sun. [4] [5] [6]

The layer outside the photosphere is the chromosphere. This layer of the solar atmosphere emits very little light and is very transparent, so it is usually not visible. However, during a solar eclipse, when the photosphere is covered by the moon, the ring or halo that is visible is the chromosphere. [7] [8] [9] [10]

The outermost part of the solar atmosphere is called the corona. Like the chromosphere, the corona is also not visible except during an eclipse. Surprisingly, the temperature of the chromosphere is much higher than that of the photosphere and the temperature of the corona is much higher than the chromosphere. But since the Sun's energy is generated at its center,

the temperature of the area near the center, i.e., the photosphere, should be higher. And this is one of the biggest mysteries of the Sun. [11] [12] [13] [14]

A comet usually has a head and a tail. The comet's tail is always in the opposite direction of the Sun, no matter which direction it goes. But why?

In the corona outside the Sun, the gas particles are very hot and fast. As a result, the Sun's gravitational force cannot hold these gases. Consequently, these particles spread out into the solar system at high speed. And the emission of these particles from the Sun's atmosphere is named by astrophysicist Eugene Newman Parker as the solar wind. Parker wrote a paper on the solar wind, but there were several oppositions to his hypothesis at that time. In 1958, he submitted his paper to The Astrophysical Journal for publication, but it was rejected twice. Later, the journal's editor Subrahmanyan Chandrasekhar accepted Parker's paper. [15] [16] [17] [18] [19]

It is estimated that the Sun's brightness increases by 10% every billion years. Hence, the temperature of the earth should also increase. However, there is no evidence of this in the fossil record. It is believed that the greenhouse effect is responsible for the discrepancy in the fossil record. Additionally, it is possible that the sun was much larger at the time of its birth, but its mass was lost due to solar winds. [1] Astronomical calculations suggest that the sun loses 1-2 million tons per second through the solar wind. Nevertheless, this is insignificant compared to the sun's immense size. The solar wind is detrimental to life on Earth, but our powerful magnetic field and atmosphere protect us from its harmful effects. [19]

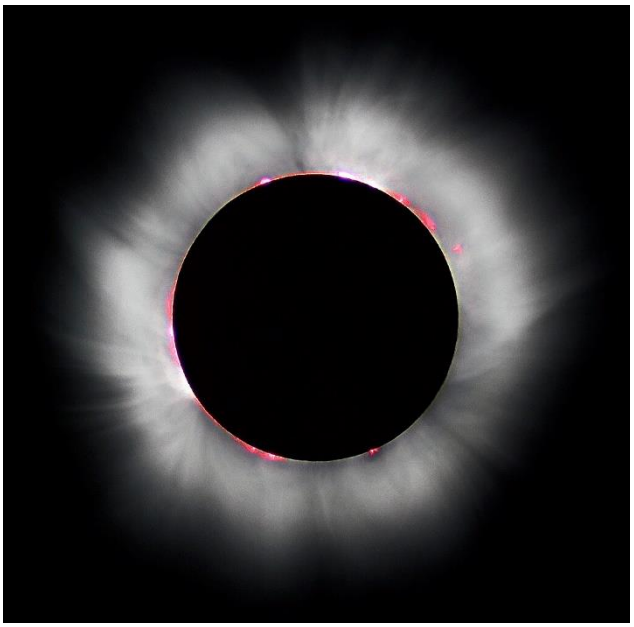


Figure 2: The chromosphere, corona and prominence of the sun during the solar eclipse of 1999

Now let's talk about sunspots. Sunspots are basically dark spots visible on the solar surface. Some of them are so large that they can be seen with the naked eye, although it is never advisable to look directly at the sun without necessary protection as it can cause permanent damage to the eyes. Sunspots appear darker when compared to other parts of the sun mainly due to their lower temperature. Furthermore, these sunspots have a very strong magnetic field.

Each sunspot lasts for several hours to several months from its birth until it disappears. The renowned scientist Galileo Galilei studied these sunspots back in 1612 and he observed that the sun rotates on its own axis and takes about a month to complete one rotation. However, recent observations suggest that different parts of the sun rotate at different speeds

with the equatorial region completing one rotation in about 25 days, while near the polar region it takes approximately 36 days. [20] [21] [22]

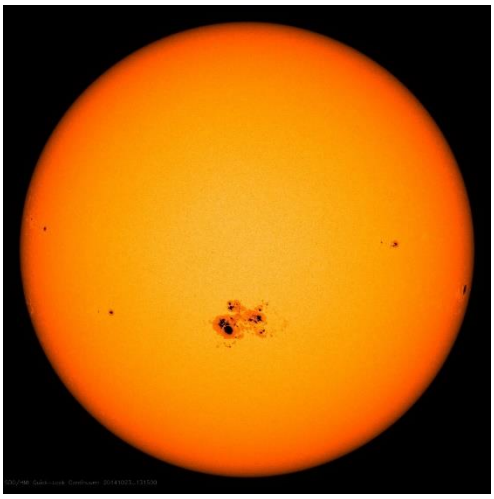


Figure 3: These black spots on the sun are our sunspots

The number of sunspots on the sun varies in a cyclical manner where, after 11 years from the occurrence of maximum number of sunspots, the occurrence reaches a minimum and another 11 years later, maximum number of sunspots are observed again. And this cycle continues. [21] [23] [24]

The substances that make up the interior of the sun are transformed into a kind of charged gas due to the extreme heat, which is called plasma. When these plasmas move inside the sun, they create magnetic fields. Every 11 years, the sun's magnetic field changes from a strong and complex shape to a weak and simple shape. And 11 years later, the magnetic field becomes complex and powerful again and this change of the magnetic field from strong to weak continues in a cycle. And it is when the magnetic field is strong and complex that sunspots are most frequently observed. Where the magnetic field of the sun is strong, the hot plasma within the sun cannot rise, leading to lower temperatures in that area compared to other parts of the sun, creating solar spots. For this reason, even the smallest sunspots are at least 500 km in size. [1] If it is smaller than this, radiation from the surrounding area destroys it.

Sunspots on the sun experience changes in their numbers, increasing and decreasing every 11 years. Some associate this phenomenon with match some disasters that occurred on earth, but there is no definite evidence to support this. [25] [26]

Every 11 years, the sun's magnetic field reverses direction. That is, the south pole shifts and takes the place of the north pole and the north pole too shifts and takes the place of the south pole. This is called the solar cycle. When the cycle is in the midway, the number of solar spots is highest. That is, when the solar cycle is half the way, the sun's magnetic field becomes the most powerful and complex. However, it is still unknown why the sun's magnetic field flips like this. [27] [26]

Surprisingly, the same phenomenon happens to the earth's magnetic field. That is, the earth's magnetic field flips too. On average, the earth's magnetic field reverses once every 300,000 to 1,000,000 years. The molten rock that emerges from the ocean floor gets the orientation of the magnetic field. So, when the magnetic field reverses, the orientation of the new molten rock is opposite to that of the old rock. There are also many other evidences that suggest that the magnetic field in fact reverses. According to the data obtained so far, the strength of the magnetic field declines to zero at one stage of the reversal. As a result, there is nothing to

protect the earth from the solar wind at that moment. Then, due to these particles and radiation, genetic damage should be observed in biodiversity, but no conclusion has been reached in the research yet. [29] [28]

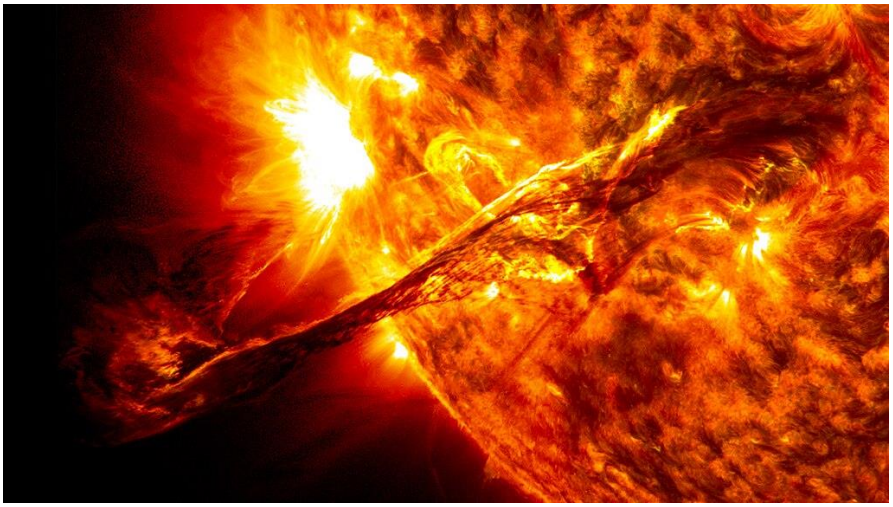


Figure 4: Solar prominence captured by NASA's Solar Dynamics Observatory

Occasionally, one can see parts of the Sun's chromosphere, or photosphere, extending like a filament to the corona. These are called solar prominences. Sometimes these filaments take the shape of a loop. Their origin is uncertain, but they are probably related to the sun's magnetic field. Solar prominences are one of the most spectacular events on the sun's surface. [30] [31] [32]

However, the most spectacular and catastrophic event on the sun's surface related to the magnetic field is the solar flare. When the magnetic field near the sunspot becomes very complex, a huge amount of energy is suddenly released. This event is called a solar flare. Sometimes, in effect of a solar flare, a lot of material is scattered from the sun's corona at high speed. In some cases, the energy and material that comes out by a solar flare from the sun hits the earth, causing various difficulties on the earth. [33] [34] In 1859, due to a solar flare, the amount of aurora on the earth increased significantly. Although auroras are usually seen near the poles, at that time auroras were seen further inside from the polar regions. According to some descriptions, the light of this aurora was so strong that people woke up from sleep in the middle of the night and started thinking that it was daylight. At that time in history, regions of the earth were getting connected by telegraph. Due to that solar flare, sparks were seen coming out of the telegraph machine and the open wire.

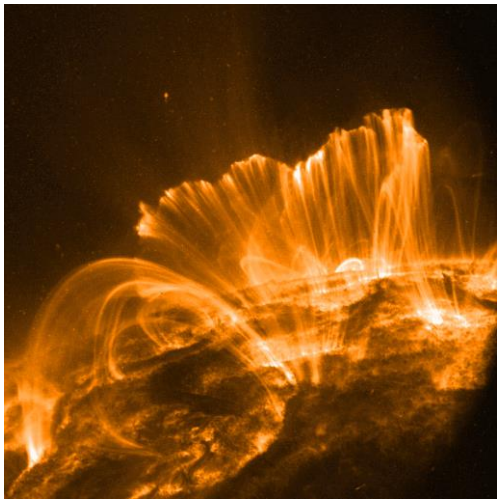


Figure 5: Solar flare captured by NASA's TRACE satellite

Due to the solar flares, the earth's atmosphere heats up and spreads outward. As a result, the satellites in space lose their orbit. In 1989, due to a solar flare, a system that was tracking nearly 19,000 satellites temporarily lost track of about 11,000 satellites. In some cases, many satellites

are even destroyed. As it happens, the International Space Station sometimes has to be returned to its original orbit. Many times, the satellite's machinery is permanently damaged. Mobile phones and the internet on Earth suffer temporary disruptions, and transformers are sometimes burned. In 1989, some parts of Canada were without electricity for almost 9 hours. The astronauts too in space have to face this deadly radiation. For comparison, just on a normal day, the amount of radiation that an astronaut had to endure in the Rassan Mir spacecraft was equal to eight times the chest X-ray! [35]
Nevertheless, although the Sun's magnetic field causes all these complications, it also protects our solar system. The Sun's magnetic field combined with solar wind create a layer around the entire solar system, called the heliosphere. This heliosphere protects the planets from radiation coming from outside the solar system. [36] [37]

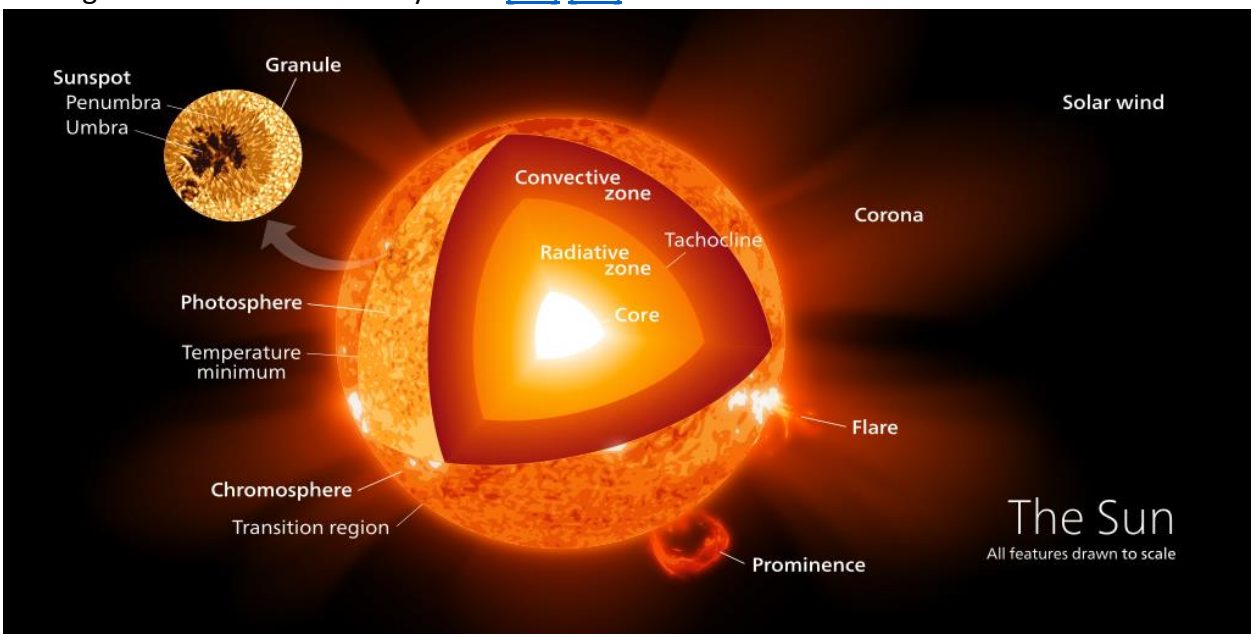


Figure 6: All the common features of the sun in one image

Let's discuss a bit about the energy of the sun. Each second, the sun produces an energy output of 4 × 10^26 joules, an inconceivable amount of energy. Even if we installed a trillion 100-watt bulbs in each of a trillion cities, this energy would still be three times more than what is consumed in all these cities. The trillion number is like this, 1,000,000, 000,000. Where does this huge amount of energy come from? The answer is known to many, the nuclear fusion reaction at the core of the sun where 620 million metric tons of hydrogen are converted to helium every second. However, humans were not aware of this in the past. When meteoroids collide with the sun, light and heat are generated; the sun is constantly shrinking and heat is produced from this contraction; various such hypotheses come up from time to time. [38]

When the brightness of some stars is graphed against their surface temperatures, it is called the Hertzsprung–Russell diagram. Most stars on this graph occupy a place on the upper left. These stars are known as the main sequence stars. [40] [41] [42] [43] In other words, stars that produce helium by fusing hydrogen at their core are called main sequence stars. Ninety percent

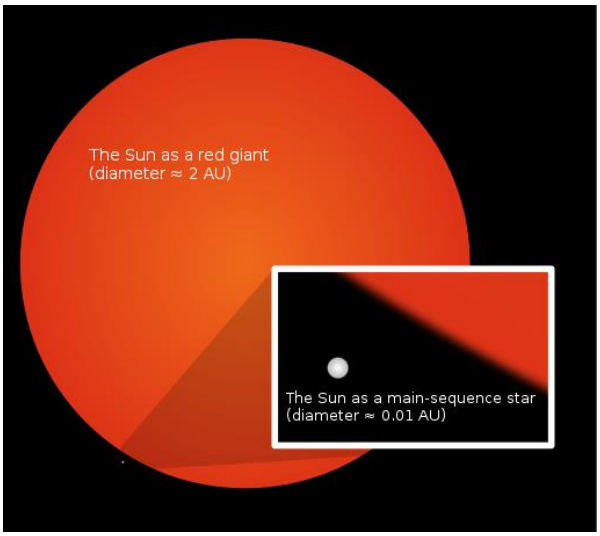


Figure 7: Comparison of the current-day Sun and the Sun as a red giant in the future.

of the stars in the universe are of this type. [39] Our sun is one such star. At the core of the sun, fusion of hydrogen produces helium, and this is forming a helium deposit there. The sun is in the midway of a transition where there will be no more hydrogen left in the core of the sun. Only helium will remain and this helium will be surrounded by a shell-like structure of hydrogen. Hydrogen will fuse in this shell-like form, but the helium in the center will remain inactive. The sun will slowly pull-out of its mani sequence stage. Due to the release of excess energy, the outer part of the sun will expand. The size of the sun will become so enormous that it will engulf planets such as Mercury and Venus. The life-giving sun will become a life-threatening star, the cause of life destruction. The sun's color will turn red, turning into a new type of star, called red giants. [44]

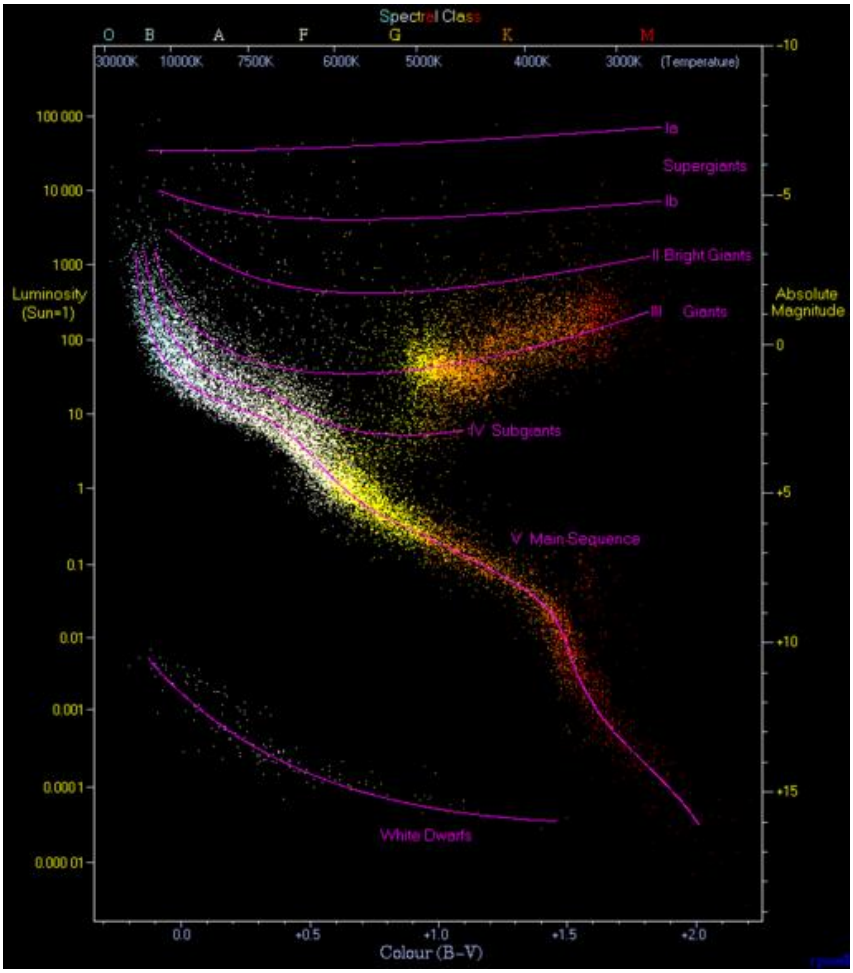


Figure 8: An H-R diagram of 22000 stars

At one point, due to the excess heat and pressure, the helium collected at the core will begin nuclear fusion. Helium will fuse, forming carbon, and the temperature in the core will increase further. As a result, the rate of fusion of helium will continue to increase. Within a few minutes, all of the helium at the center of the sun, which would constitute about 40% of the sun's mass, will undergo fusion. This will produce so much energy that for a brief moment, the brightness of the sun's center will be the same as that of all the Milky Way's stars combined. This is

called a helium flash. After this burst of light, the sun's size and brightness will decrease again. At that stage, the sun will be called a helium main-sequence star. After a while, the same course of events will repeat. The sun will again turn into a red giant. But this time there will be a smaller helium flash than before. And again, the course of events will repeat. After four or five such incidents, the outer layer of the sun, consisting about 45 percent of the sun's mass, will gradually disperse into space and form a nebula, leaving behind a white and very dense core of the sun. Gradually, the remaining burning materials at the center of the sun will be exhausted. Ultimately, the sun will turn into a white dwarf. It will no longer produce any energy, but will continue to radiate the remaining energy that was produced earlier. [45]

Let us now engage with helium slightly. Helium all of a sudden? What is the matter?

In the past, the suns composition was thought to be like the earth. However, at that time, there was no means to directly observe the Sun without gazing straight into its glare. Thus, during a solar eclipse, it was easier to observe the Sun. At the times of total solar eclipse, the observers would marvel at the crimson ring, specifically the corona of the sun. In some cases, red filaments were also seen, which are now called Solar Prominence. [46]

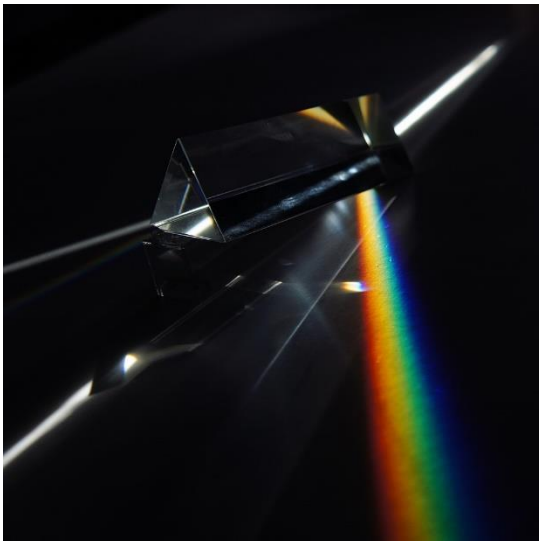


Figure 9: White light, decomposed into the seven bands of a rainbow

Now, let us delve into the realm of optics; don't worry, it will be shallow. When we see all the colors of light together, we see it as white light. During daylight hours, we are able to see objects because the light from the Sun reaches those objects and then reflects back to our eyes. However, not all light falling upon an object is reflected, for some of it is absorbed. For instance, a red rose absorbs all colors except red, and reflects the red light to our eyes, so we see the rose as red. Again, if an object is lime green, it probably reflects green and yellow colors and absorbs all the other colors. [47] A spectroscope is a device that can separate light into its constituent parts. When we look at the light from an object with a spectroscope, we can see the colors that make up that light. [48]

People have known for a long time that when white light enters a prism, it splits into seven colors of the rainbow. So, what the scientist Isaac Newton did was, he darkened his whole room and made a hole in the window. And he held a triangular prism in front of the hole. He then passed each of the seven colors of light through a second triangular prism. However, in this case, the colors did not undergo any further alteration. That is, if red light entered, it exited as red. But when Newton passed all of that split light through another prism, it turned white again. Much later, in 1802, William Hyde Wollaston, the discoverer of the elements, palladium and rhodium, passed light through a rectangular hole, where Newton's window had a circular hole,

and a rectangular prism. This elicited a more stunning and precise display of a spectrum. Another thing Wollaston noticed was that amidst the light splitting into red, blue, green, and other colors, there were certain dark lines present. However, Wollaston did not delve deeper than that. [49] [50]

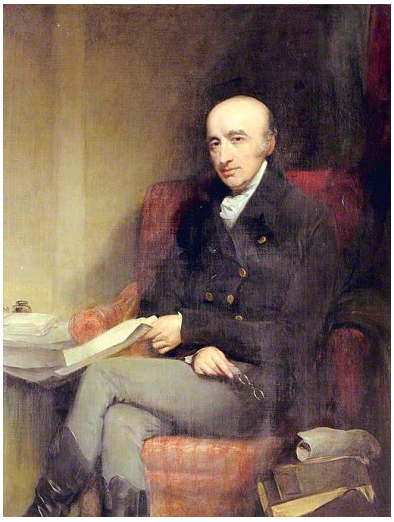


Figure 10: William Hyde Wollaston

Twelve years after Wollaston's discovery, in 1814, Joseph von Fraunhofer, a German physicist and lens manufacturer, created a similar device to Wollaston's, which he named a spectroscope. Using this spectroscope, he observed those dark lines that Wollaston had noticed and named them with the eight letters A to H. Based on these lines, he began to produce lenses of better quality. However, he was not aware of Wollaston's 1802 work. These lines were later named Fraunhofer lines. [50] [51]

Around 1854, German scientists Robert Wilhelm Eberhard Bunsen and Gustav Kirchhoff made a spectroscope and started experimenting with it. Later, in 1859, Kirchhoff formulated three laws on how different types of spectra are emitted from different types of substances. With these laws, gas at low pressure, gas at high pressure, liquid, solid, etc. can be identified. And according to these laws, the black lines of the Fraunhofer lines indicate in fact the absorbed parts of the white light. For example, if an object absorbs the 'D' line, a black line will be seen at the 'D' position in the spectroscope. Bunsen and Kirchhoff also showed that the spectrum emitted from an element is always the same and unique, much like a fingerprint. However, some scientists had already got a hint this result of their research through their own research. [52] [53]

Between 1830 and 1860, only two new elements were discovered - lanthanum and erbium. But relying on their discovery, Bunsen and Kirchhoff discovered and named a new element caesium in 1860. The word caesium comes from caesius, which means blue. They named the element so because they saw two blue lines in the spectrum of caesium. A few months later, they discovered another new element, rubidium, and named it after the Latin word "rubidus", which means dark red. In addition, Kirchhoff proposed a theory on the composition of the sun after observing the sun with his spectroscope and gave rise to the idea that the sun is covered with vapors of various elements. [52] [54]

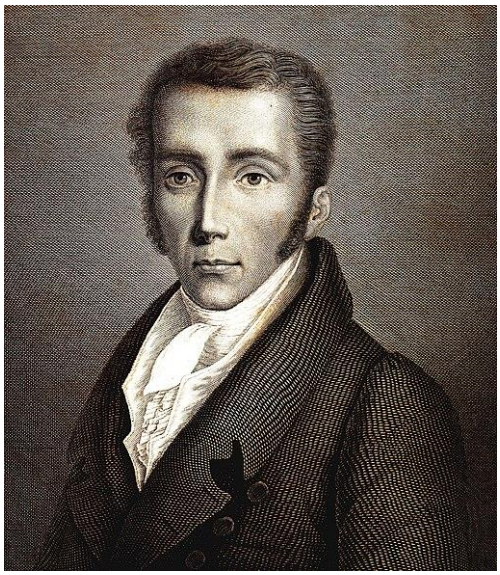


Figure 11: Joseph von Fraunhofer

I mentioned something a few paragraphs back. During a total solar eclipse, the corona of the sun can be seen,

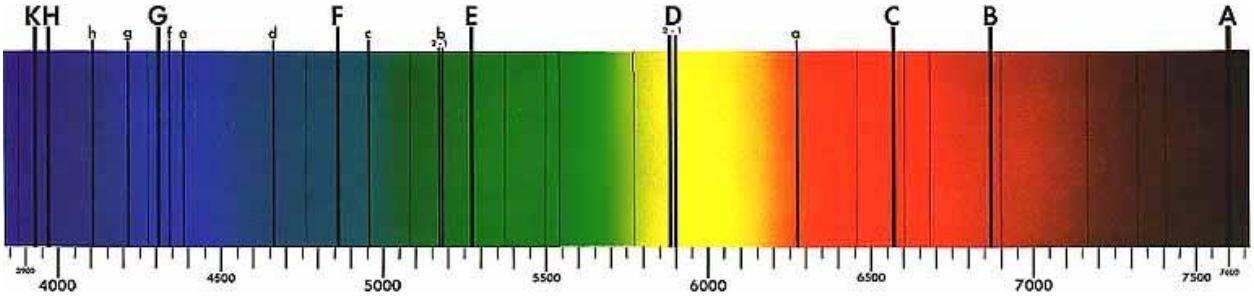


Figure 12: Fraunhofer lines

solar prominence can be seen. Different people proposed different hypotheses about the structure of the sun. Joseph Norman Lockyer, a British astronomer and the founder and first editor of the famous Nature journal, observed solar spots for several years with a spectroscope. Lockyer and his friend Balfour Stewart believed that solar prominences were made of gases. Lockyer also believed that the brightness of other parts of the Sun prevented these prominences from being easily seen at other times. If observed with a very fine spectroscope, they can be seen at other times than the solar eclipses. Lockyer published his idea in 1866 and applied to the government for such a spectroscope. Construction of his spectroscope began in 1867. [55] [56]

Figure 13: German scientist Robert Bunsen

There was a total solar eclipse on 18th August 1868. Prior to this event, several scientists proposed hypothesis regarding the composition of the sun. In order to witness the solar eclipse that took place in 1868, astronomers had to come to India. Many astronomers were present in India at that time, but unfortunately, the construction of Lockyer's spectroscope was not finished yet. However, other astronomers observed the sun that day with the help of spectroscopes and confirmed according to Kirchhoff's formula that the solar prominence was indeed composed of gas. There, they saw the spectrum of hydrogen and other elements.

Figure 14: Gustav Kirchhoff

And they also detected an unknown yellow line there. Many thought it was their familiar 'D' line, which is found in the spectrum of sodium molecules. But Norman Robert Pogson expressed some doubt. [57] [58]

When the solar eclipse ended, Pierre Janssen, an astronomer, wondered if the solar prominence could still be observed even after the eclipse. Therefore, the next day, he resumed his observations of the sun and indeed, he witnessed solar

Figure 15: Spectrum of Rubidium

Figure 16: Spectrum of Caesium

prominences. Thus, Lockyer's hypothesis proved to be correct. I must mention that Janssen did not say anything about the presence of the yellow line in his description. In a letter sent to someone, Janssen wrote about his observation this way, "They sent me here to witness a five-minute solar eclipse, and now I am going back with the permanent solar eclipse of India for them." In a letter to his mother, Janssen wrote, "The real solar eclipse for me was on August 19th." He wrote to his mother in another letter, "The real solar eclipse for me was on August 19th." [57] [59]

Figure 17: Joseph Norman Lockyer

Why won't Janssen be excited? His discovery was very significant for that time.

Afterward, Janssen spent some days in India observing the sun. Meanwhile, on October 16, 1868, Lockyer got his hands on his newly built spectroscope, although the spectroscope was not finished yet. Lockyer began observing with his unfinished spectroscope and it took him three days to calibrate everything. He started observing the sun on October 20th, and after an hour of observations, he had a view of solar prominences. And he also saw that unfamiliar yellow line in the spectrum. [60] [61]

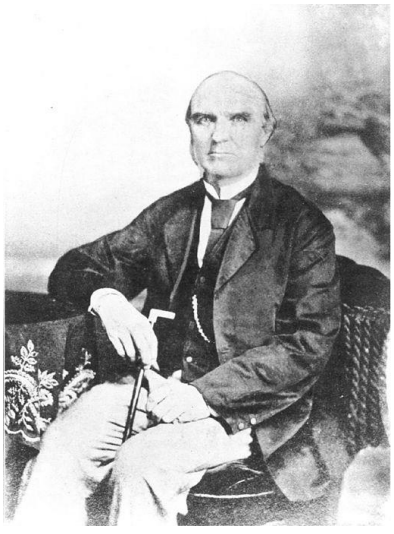


Figure 18: Norman Robert Pogson

On October 21, Lockyer's letter about the observation reached the Academy of Sciences in Paris. The funny thing is, Janssen's letter about his discovery, written on September 19 from India, also reached the Academy of Sciences just a few moments after Lockyer's letter arrived. Then a confusion rose as to who should be credited for the discovery of the solar prominences. Eventually, both Janssen and Lockyer were credited for the discovery. Janssen was in India then and was not aware of these events. Four years later, a medal with both of their pictures was made as a tribute to their credit and both Lockyer and Janssen showed great magnanimity. [60] [62]

On November 4, 1868, Father Angelo Secchi saw the yellow line again. In mid-November, Father Secchi sent a note to Lockyer

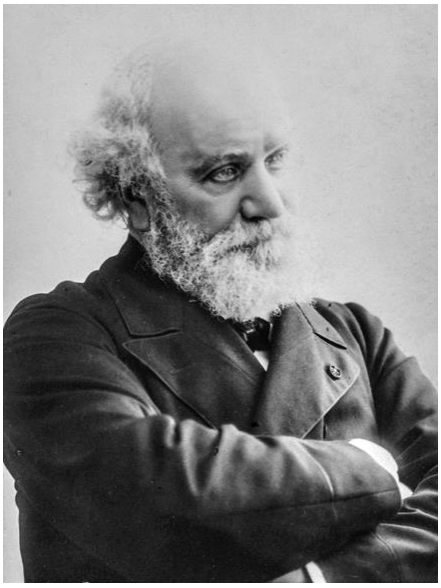


Figure 19: Pierre Janssen

about it. Lockyer became sure that the line was not from sodium but completely new. On November 30, Secchi confirmed that the line was not hydrogen either. [61] [60] [62]

In the meantime, on November 6, Lockyer discovered a layer of the sun's atmosphere. At the suggestion of his friend Dr. William Sharpey, he named it chromosphere. [60] [63]

In the winter of 1868, Lockyer sought the help of a chemist, Edward Frankland, as the yellow line was still bothering him. They started researching together, and Lockyer even began to ponder that the line might be coming from a new element. They did not find any element in their research that could conjure such a yellow line. Nor they managed to explain this phenomenon in any other way. Father Secchi named the line D3 as D1 and D2 were known lines from sodium. [62] [64] [65]

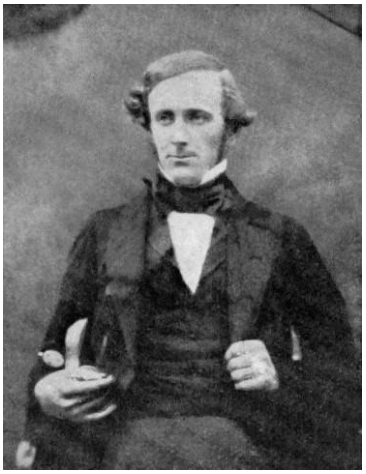


Figure 20: Edward Frankland

Over the next two years, Lockyer got himself involved in other subjects. But he never let go that new D line off his mind. At a time somewhere in 1871, he named a new element on the basis of that line. Since the line was discovered from the sun, he named it after the Greek god of sun, 'Helios'. Lockyer did not know whether the element was a metal or a non-metal. The names of metallic elements end with the suffix 'ium', i.e., Sodium, calcium, and so on. Whereas, even though hydrogen is a gas, Jean-Baptiste Dumas showed that hydrogen behaves like a metal. However, Lockyer did not publish any description of this naming. So it is not known, exactly what was in his mind when he named this element. Whatever he thought, he named the element helium. The name spread by word of mouth. Lockyer himself doubted whether the yellow line was coming from a new element or not. In a lecture in 1872, Lockyer identified the element as D3 element. In 1871, Lord Kelvin mentioned the name 'helium' for the first time in public. [64] [66]

But all the efforts of finding helium were going in vain, it was so well hidden. In 1881, Luigi Palmieri observed a yellow line in the gas emitted from the volcano Vesuvius. In the title of his report, he mentioned helium. In 1883, Heinrich Kayser mentioned helium in his textbook and wrote the symbol for the element, He. [67]

In 1887, geologist William Francis Hillebrand found a type of gas from a crystal called uraninite. He thought the gas might be carbon dioxide. But later he realized that it was not carbon

Figure 21: Uraninite crystal

dioxide. When he observed the gas with a spectroscope, he saw a nitrogen-like spectrum, but there were some other spots or lines present. Hillebrand thought that the state of the gas they were observing was affecting the spectrum. Hillebrand published his discovery in a journal. In a letter, Hillebrand wrote, "…one of us suggested that it might be due to a new element…"

Meanwhile, Lord Rayleigh was trying to measure the weight of nitrogen. He found that the mass of nitrogen collected from the atmosphere was more than the mass of nitrogen produced by chemical reactions. In 1892, he wrote about this in Nature magazine. Then William Ramsay, William Crookes and Rayleigh started working together. On April 23, 1894, Ramsay wrote to his wife in a letter, "There may be an inert gas present in the nitrogen that cannot be detected. … there's a chance that we might even be able to discover a new element." [68] [69]

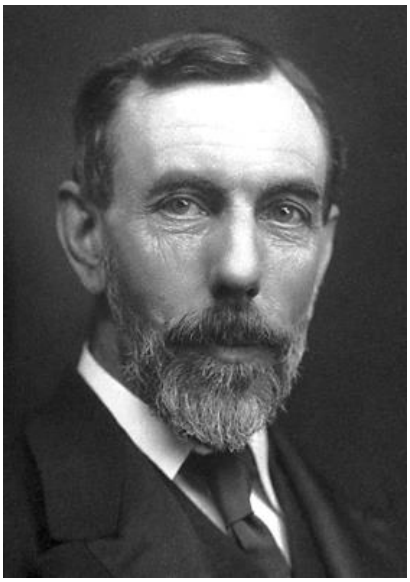


Figure 22: William Ramsay

After that, probably in June, Ramsay wrote to Rayleigh in a letter, "I have probably been able to separate the gas." He called this gas "Q". Later, the gas was named argon. It is from a Greek word meaning 'lazy'. The gas is so named because it does not usually react with anything. That is, the gas is inert or lazy. On 31 January 1895, the discovery of argon was made public at the Royal Society. [71] [70]

Ramsay then guessed that there might be another gas like argon, which he named krypton. A similar assumption was made by Lecoq de Boisbaudran and some other chemists. Around that time, Henry Miers of the British Museum came across Hillebrand's paper. He then told Ramsay about it. Ramsay started his research accordingly. And he did find a new kind of gas that he thought was krypton. He also sent some of that gas to Crookes. On March 23, 1895, Crookes wrote to Ramsay, "Come and see it, krypton is in fact helium." On March 24, 1895, Ramsay wrote to his wife in a letter, "…I could see a yellow line with the spectrum of argon… I told Crookes of this, and on Saturday morning when I, Harley and Shields were working, Crookes sent a telegram… Helium is the name given to a line in the solar spectrum, known to belong to an element which is unknown so far. 'Krypton' was what I called the gas that I sent to Crooks…" [71] [72]

So, at last, helium was discovered on Earth. A year later, Lockyer wrote in a paper, "…The twenty-six-year-old helium has finally been seen in a laboratory on Earth." [72]

Figure 23: Spectrum of Helium

However, Ramsay initially had some doubts about whether his discovery was really a new element; later, however, this was dispelled. [72] On March 28, 1895, Ramsay sent a bottle of helium gas to Lockyer. Lockyer performed a spectroscopic analysis of it. In that spectrum, he saw some new lines that were not found in the sun's spectrum. In the first week of May, Lockyer found that some stars' spectra had some lines that were not yet identified as coming from any element, were actually part of the helium spectrum. But why are these lines not present in the sun's spectrum? It was later found out that it was actually a matter of temperature. [73]

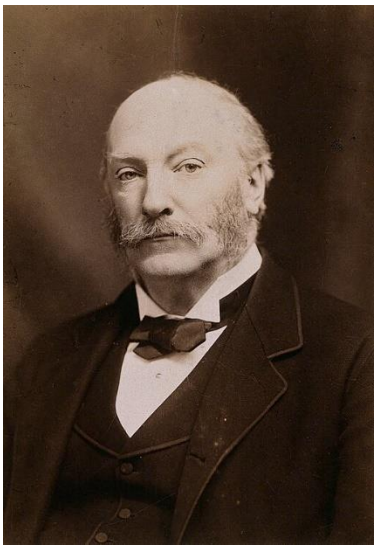


Figure 24: Lord Rayleigh

In May 1895, two German physicists, Carl Runge and Friedrich Paschen, showed that the yellow line of helium found on Earth was not one, but two lines. And they also saw a green line there. They then said that if the yellow line from the sun was not a mixture of two lines, then the spectrum of Ramsay's discovered gas and the D3 line are not the same. Runge and Paschen started observing the sun and in July they found that D3 was also a double line. But they noticed another thing, that the yellow and other lines of Ramsay's discovered gas spectrum were not one, but two fine lines. [74] [75]

Runge and Paschen did not stop working on that gas. They said that the reason for having two lines like this could be that this gas was actually a mixture of two elements, one of which is helium. They named the second element 'X'. Lockyer named that element 'oronium' or 'astereium', as some of its spectral lines can be found in the Orion nebulae and other stars.

And in the periodic table of that time, there were supposed to be more elements between hydrogen and lithium. H. N. Stokes wrote in Science magazine in October 1895, "According to the research of Crookes, Lockyer, Runge, Paschen and others, what we now call helium is actually a mixture of two or more unknown gases." [75]

Lots of attempts were taken to find that element. Some even claimed to have found it. Ramsay and Morris William Travers kept working on inert gases. According to Mendeleev's periodic table, there should be some more gases like helium and argon that would be inert, meaning

they would not participate in any reaction. Ramsay and Travers were searching for them. And yeah, hey succeeded. They discovered ‘neon’ (meaning new), ‘krypton’ (meaning hidden) and ‘xenon’ (meaning stranger). There are seven elements in the group of inert gases in the current periodic table and Ramsay in whatever way was involved in the discovery of five of them! Ramsay and Rayleigh were awarded the Nobel Prize in 1904. [76] [77]

But it took a few more years for the helium problem to solve. Finally, the problem of helium spectrum was solved by quantum mechanics. Based on Niels Bohr’s theory, Evan J. Evans explained the helium spectrum. [77]

So, now the question arises, who is the discoverer of helium? Encyclopedia Britannica has credited Lockyer, Ramsay and Janssen. [78] Ramsay also mentioned the name of Nils Abraham Langlet when he received his Nobel Prize. Langlet independently had a glimpse of helium at the Thiodol Clive laboratory two weeks after Ramsay’s discovery of helium on April 8, 1895.[79] Unfortunately, the names of Pogson and Langlet have been forgotten. And Janssen, point to be noted, did not mention any yellow lines in his description. [80]

There are some villains who try to distort history and raise their own names. It should be remembered that Janssen did not try anything like that. His descriptions were clear. He did not detect any yellow lines. [81]

The discovery of helium shows another thing plain as day. We always hear stories of various scientific discoveries, where a scientist does this and that research and suddenly discovers something and shouts ‘Eureka’, it teaches us to doubt these stories. [82] In fact, every discovery has contributions from many, and there are many heroes behind that discovery. And many of them are forgotten. Even if a person has a very small contribution to a discovery, we should always ponder, whether this huge building could stand without his small stitch. And history, it is written by the victors.

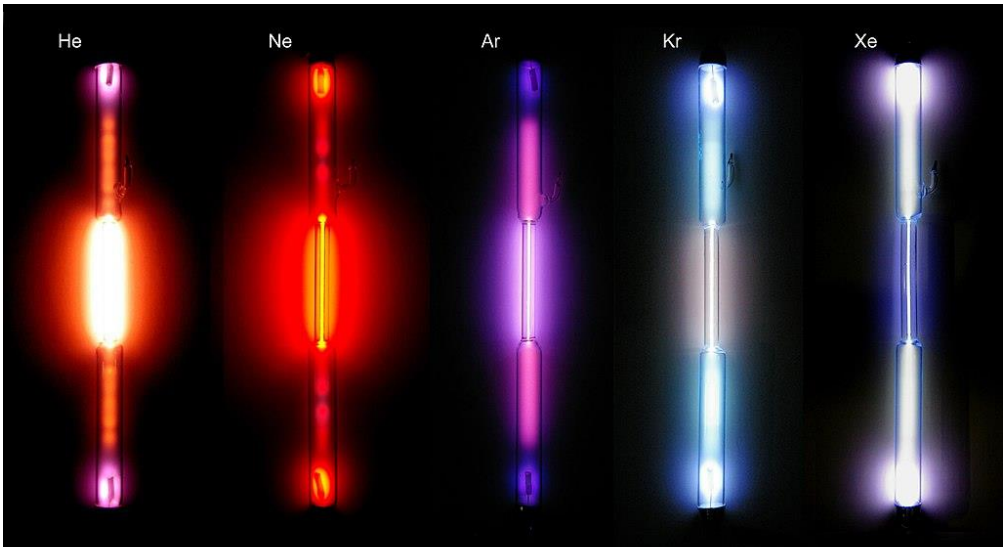


Figure 25: Five inert gases, on the discovery of each of them, Ramsay was involved

1. Lang, Kenneth and Zirin, Harold. "Sun". Encyclopedia Britannica, 8 Sep. 2023, https://www.britannica.com/place/Sun. Accessed 13 September 2023.
2. In Depth | Sun – NASA Solar System Exploration; In Depth | Sun – NASA Solar System Exploration (archive.org);
3. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-951693-50-3; page 494-496;
4. Zirin, Harold. "photosphere". Encyclopedia Britannica, 2 Sep. 2023, https://www.britannica.com/science/photosphere. Accessed 13 September 2023.
5. The Surface of the Sun | Center for Science Education (ucar.edu); The Surface of the Sun | Center for Science Education (archive.org);
6. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-951693-50-3; page 497-499;
7. The Colorful Chromosphere: Sun's Lower Atmosphere | Center for Science Education (ucar.edu); The Colorful Chromosphere: Sun's Lower Atmosphere | Center for Science Education (archive.org);
8. NASA/Marshall Solar Physics; NASA/Marshall Solar Physics (archive.org);
9. Britannica, The Editors of Encyclopaedia. "chromosphere". Encyclopedia Britannica, 29 Jul. 2019, https://www.britannica.com/science/chromosphere. Accessed 13 September 2023.
10. Chromosphere - NSO - National Solar Observatory; Chromosphere - NSO - National Solar Observatory (archive.org);
11. Britannica, The Editors of Encyclopaedia. "corona". Encyclopedia Britannica, 25 Feb. 2019, https://www.britannica.com/science/corona-Sun. Accessed 13 September 2023.
12. NASA/Marshall Solar Physics; NASA/Marshall Solar Physics (archive.org);
13. The Hidden Corona: Sun's Outer Atmosphere | Center for Science Education (ucar.edu); The Hidden Corona: Sun's Outer Atmosphere | Center for Science Education (archive.org);
14. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-951693-50-3; page 500-502;
15. Parker, E. N. (1997), "The martial art of scientific publication", *EOS Transactions*, **78** (37): 391, Bibcode:1997EOSTr..78..391P, doi:10.1029/97EO00251
16. Britannica, The Editors of Encyclopaedia. "solar wind". Encyclopedia Britannica, 29 Aug. 2023, https://www.britannica.com/science/solar-wind. Accessed 13 September 2023.
17. What is the solar wind? | University of Chicago News (uchicago.edu); What is the solar wind? | University of Chicago News (archive.org);
18. NASA/Marshall Solar Physics; NASA/Marshall Solar Physics (archive.org);
19. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-951693-50-3; page 502-503;
20. Britannica, The Editors of Encyclopaedia. "sunspot". Encyclopedia Britannica, 28 Jul. 2017, https://www.britannica.com/science/sunspot. Accessed 13 September 2023.
21. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-951693-50-3; page 504-506;
22. Solar Rotation Varies by Latitude | NASA; Solar Rotation Varies by Latitude | NASA (archive.org);
23. Zirin, Harold. "solar cycle". Encyclopedia Britannica, 23 Aug. 2023, https://www.britannica.com/science/solar-cycle. Accessed 13 September 2023.
24. What is the Solar Cycle? | NASA; What is the Solar Cycle? | NASA (archive.org);
25. Understanding the Magnetic Sun | NASA; Understanding the Magnetic Sun | NASA (archive.org);
26. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-951693-50-3; page 504-509 and 517-519;
27. Zirin, Harold. "solar cycle". Encyclopedia Britannica, 23 Aug. 2023, https://www.britannica.com/science/solar-cycle. Accessed 17 September 2023.

28. Pole Reversal Happens All The (Geologic) Time | NASA; Pole Reversal Happens All The (Geologic) Time | NASA (archive.org);
29. McPherron, Robert L.. "geomagnetic field". Encyclopedia Britannica, 1 Sep. 2023, https://www.britannica.com/science/geomagnetic-field. Accessed 17 September 2023. Sources of variation in the steady magnetic field: Reversals of the main field;
30. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-951693-50-3; page 510;
31. Britannica, The Editors of Encyclopaedia. "solar prominence". Encyclopedia Britannica, 28 Jan. 2013, https://www.britannica.com/science/solar-prominence. Accessed 17 September 2023.
32. What is a solar prominence? | NASA; What is a solar prominence? | NASA (archive.org);
33. Britannica, The Editors of Encyclopaedia. "solar flare". Encyclopedia Britannica, 11 Sep. 2023, https://www.britannica.com/science/solar-flare. Accessed 17 September 2023.
34. What is a solar flare? | NASA; What is a solar flare? | NASA (archive.org);
35. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-951693-50-3; page 511-516;
36. Gregersen, Erik. "heliosphere". Encyclopedia Britannica, 10 Sep. 2018, https://www.britannica.com/science/heliosphere. Accessed 17 September 2023.
37. Heliosphere | Science Mission Directorate (nasa.gov); Heliosphere | Science Mission Directorate (archive.org);
38. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-951693-50-3; page 527, 529-530 and 534-535;
39. Types | Stars – NASA Universe Exploration; Types | Stars – NASA Universe Exploration (archive.org);
40. The Hertzsprung-Russell diagram - CESAR - Cosmos; The Hertzsprung-Russell diagram - CESAR - Cosmos (archive.org);
41. Hertzsprung-Russell Diagram | COSMOS (swin.edu.au); Hertzsprung-Russell Diagram | COSMOS (archive.org);
42. Britannica, The Editors of Encyclopaedia. "Hertzsprung-Russell diagram". Encyclopedia Britannica, 8 Jun. 2021, https://www.britannica.com/science/Hertzsprung-Russell-diagram. Accessed 18 September 2023.
43. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-951693-50-3; page 602 and 604;
44. The Sun's Evolution (northwestern.edu); The Sun's Evolution (archive.org);
45. The End Of The Sun (northwestern.edu); The End Of The Sun (archive.org);
46. Helium: The Disappearing Element | SpringerLink; Wheeler M. "Bo" Sears, Jr. pp 40;
47. Color (purdue.edu); Color (archive.org);
48. Spectroscopy: Reading the Rainbow (hubblesite.org); Spectroscopy: Reading the Rainbow (archive.org);
49. Helium: The Disappearing Element | SpringerLink; Wheeler M. "Bo" Sears, Jr.; pp 31-32;
50. The Story of Helium and the Birth of Astrophysics | SpringerLink; Biman B. Nath; pp 23-25;
51. Helium: The Disappearing Element | SpringerLink; Wheeler M. "Bo" Sears, Jr.; pp 32-34;
52. Helium: The Disappearing Element | SpringerLink; Wheeler M. "Bo" Sears, Jr.; pp 34-38;
53. The Story of Helium and the Birth of Astrophysics | SpringerLink; Biman B. Nath; pp 27-30 and 35-42;
54. The Story of Helium and the Birth of Astrophysics | SpringerLink; Biman B. Nath; pp 42-43;
55. The Story of Helium and the Birth of Astrophysics | SpringerLink; Biman B. Nath; pp 110-116;

56. Helium: The Disappearing Element | SpringerLink; Wheeler M. "Bo" Sears, Jr.; pp 41-42;
57. Helium: The Disappearing Element | SpringerLink; Wheeler M. "Bo" Sears, Jr.; pp 42-44;
58. The Story of Helium and the Birth of Astrophysics | SpringerLink; Biman B. Nath; pp 153-157 (155-156) and 161-162;
59. The Story of Helium and the Birth of Astrophysics | SpringerLink; Biman B. Nath; pp 163-172 (166 and 171 for the letters);
60. Helium: The Disappearing Element | SpringerLink; Wheeler M. "Bo" Sears, Jr.; pp 45-46;
61. The Story of Helium and the Birth of Astrophysics | SpringerLink; Biman B. Nath; pp 176-177;
62. The Story of Helium and the Birth of Astrophysics | SpringerLink; Biman B. Nath; pp 178-183;
63. The Story of Helium and the Birth of Astrophysics | SpringerLink; Biman B. Nath; pp 185-186;
64. Helium: The Disappearing Element | SpringerLink; Wheeler M. "Bo" Sears, Jr.; pp 47-49;
65. The Story of Helium and the Birth of Astrophysics | SpringerLink; Biman B. Nath; pp 189-192;
66. The Story of Helium and the Birth of Astrophysics | SpringerLink; Biman B. Nath; pp 192-194;
67. The Story of Helium and the Birth of Astrophysics | SpringerLink; Biman B. Nath; pp 213-215;
68. The Story of Helium and the Birth of Astrophysics | SpringerLink; Biman B. Nath; pp 230-231;
69. Helium: The Disappearing Element | SpringerLink; Wheeler M. "Bo" Sears, Jr.; pp 50-51;
70. The Story of Helium and the Birth of Astrophysics | SpringerLink; Biman B. Nath; pp 232-233;
71. Helium: The Disappearing Element | SpringerLink; Wheeler M. "Bo" Sears, Jr.; pp 52;
72. The Story of Helium and the Birth of Astrophysics | SpringerLink; Biman B. Nath; pp 234-236;
73. The Story of Helium and the Birth of Astrophysics | SpringerLink; Biman B. Nath; pp 237;
74. Helium: The Disappearing Element | SpringerLink; Wheeler M. "Bo" Sears, Jr.; pp 54;
75. The Story of Helium and the Birth of Astrophysics | SpringerLink; Biman B. Nath; pp 240-242;
76. Helium: The Disappearing Element | SpringerLink; Wheeler M. "Bo" Sears, Jr.; pp 55;
77. The Story of Helium and the Birth of Astrophysics | SpringerLink; Biman B. Nath; pp 240-242;
78. Britannica, The Editors of Encyclopaedia. "helium". Encyclopedia Britannica, 15 Aug. 2023, https://www.britannica.com/science/helium-chemical-element. Accessed 18 September 2023.
79. The Story of Helium and the Birth of Astrophysics | SpringerLink; Biman B. Nath; pp 238;
80. The Story of Helium and the Birth of Astrophysics | SpringerLink; Biman B. Nath; pp 249-251;
81. The Story of Helium and the Birth of Astrophysics | SpringerLink; Biman B. Nath; pp 256-257;
82. The Story of Helium and the Birth of Astrophysics | SpringerLink; Biman B. Nath; pp 251-255;

Eight Wanderers and One Starry-Eyed

Mercury, Venus, Earth and Mars, Jupiter and Saturn, and Uranus and Neptune, the planets of the solar system can be divided into these three groups based on their composition. These are, respectively, the rocky planets, the gas giants, and the ice giants. [1]

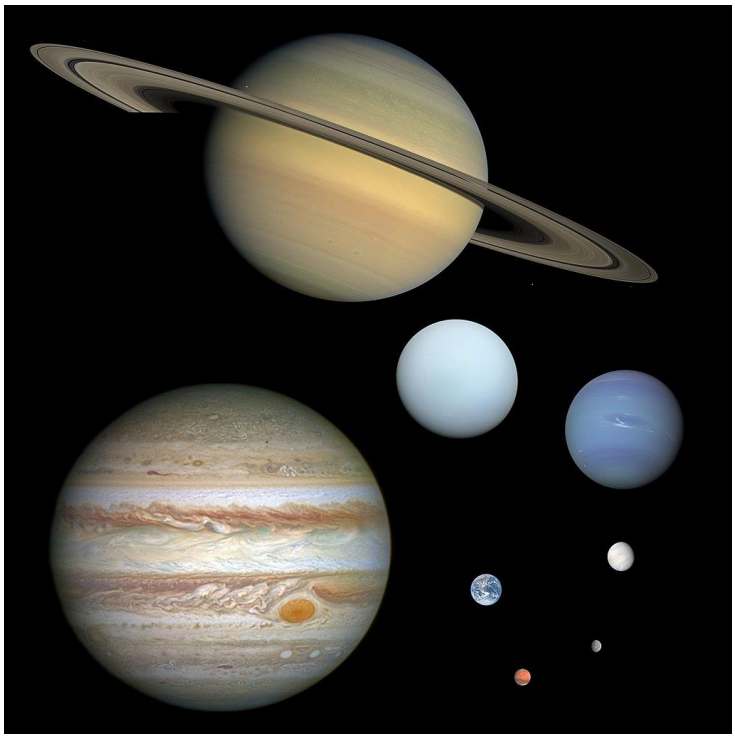


Figure 1: All the planets of the solar system in one frame

Jupiter is the largest planet in the solar system. Everyone knows that, right? Still, I repeated that known fact hoping that you won't be offended. (You figure it out why you might be offended) Jupiter is probably the oldest planet in the solar system. Its mass is almost three hundred and eighteen times that of Earth. Its density is almost equal to that of the Sun. And in terms of volume, it is one thousand three hundred and twenty-one times that of Earth. Doesn't the mass seem too low compared to that immense volume? It does and the reason is simple, Jupiter is a gas giant. That is, while the Earth is made up of solids, Jupiter is composed mainly of hydrogen gas. Even then, Jupiter is the heaviest and most influential object in the solar system after the Sun. If you add up all the planets in the solar system, the mass will still be less than half of Jupiter's mass. [2] [3] [4] [5] [6]

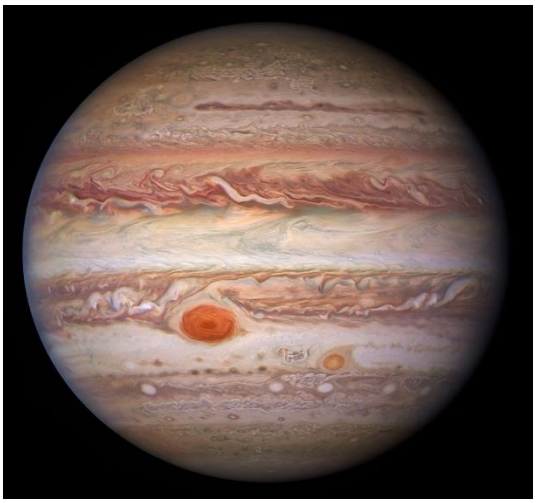


Figure 2: An image of Jupiter with the Giant Red Spot visible. It is just that red eyelike structure.

According to one hypothesis, Jupiter was born a little closer, at 3.5 AU from the sun, than today's distance from the Sun to Jupiter which is 5.2 AU (AU, Astronomical Unit which is equal to the distance from the Sun to Earth). After birth, Jupiter kept moving towards the Sun. But at one point, the gravity of Saturn stopped Jupiter's progress. Jupiter even began to move away from the Sun and finally settled in its current position. However, there are some loopholes in this hypothesis, but let us not get much deeper. (Hopefully you didn't understand. In pursuit of a dexterous escape) [7] [8]

Jupiter rotate around its axis once every ten hours. As a result, Jupiter is the planet with the shortest day in the solar system. There are big storms here and lightning and thunder too, here in Jupiter. The power of this lightning can be almost a thousand times more than the lightning

on Earth. And the size of Jupiter's storms can be bigger than the size of Earth itself. [3] [9] Giant Red Spot or Great Red Spot, a storm that has been going on in Jupiter for a long time, have a size larger than the planet Earth. The first mention of this storm is found in a picture drawn by Samuel Heinrich Schwabe in 1831. However, there is a possibility that the storm that Gian Domenico Cassini discovered in Jupiter in 1665 was in fact the Giant Red Spot. If so, then this storm has been going on in Jupiter for almost three and a half centuries. But as the days go by, its size is getting smaller. [10]

So I was talking about the influential Jupiter a while ago. How much influence does Jupiter have on the solar system?

The mass of Jupiter is so much that the center of mass of Sun and Jupiter is outside the Sun, whereas the center of mass of all other planets in the solar system are inside the Sun. The asteroid belt that is between Jupiter and Mars was also born due to the influence of Jupiter. Initially, the asteroid belt was part of the disk that formed all the solar systems planets. The other parts of the disk were gravitationally bound together and eventually became planets. However, in the case of the asteroid belt, Jupiter's gravity prevented the material of that specific section of the disk from clumping altogether and forming a planet, and it remained as an asteroid belt. And some parts of that section of disk clumped and gave rise to asteroids like Ceres and Pallas.

This huge amount of gravitational force of Jupiter causes Jupiter to pull more strongly on comets or asteroids than other planets. As a result, Jupiter has to endure more collisions with these small objects than other planets. Since Jupiter pulls these scattered comets or asteroids towards itself with a strong force, it is believed that many comets or asteroids that might be heading towards Earth are pulled by Jupiter towards itself and thus it protects the Earth. However, Jupiter also pulls many comets from afar into the inner solar system with its gravitational influence. As a result, the probability of collision of those comets with Earth or other planets increases. So, whether Jupiter actually protects the Earth or throws a comet towards the Earth is something to ponder about. [15] [16]

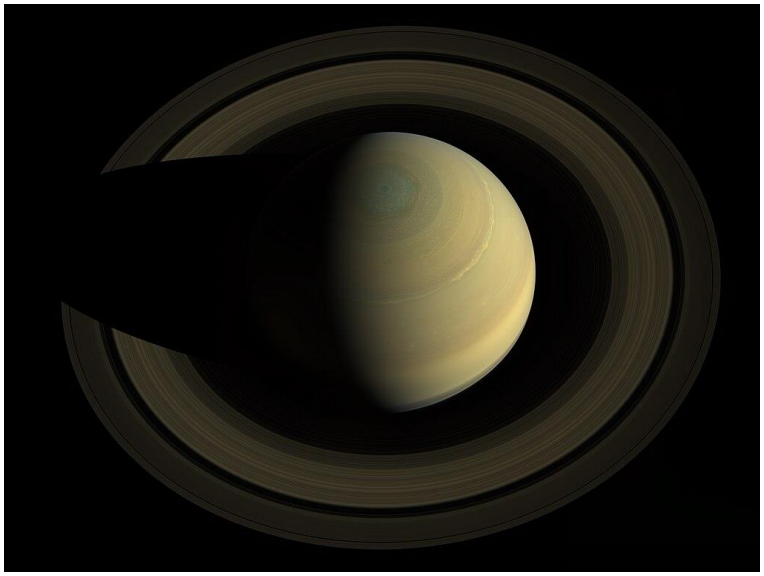


Figure 3: Image of Saturn captured by Cassini Spacecraft.

There is another gas giant in the solar system, named Saturn, the second largest planet in the solar system. Saturn is the only planet in the solar system whose average density is less than water. That is, if you put Saturn in a huge sea, Saturn will float in that water. Both Jupiter and Saturn have clouds, clouds made of ammonia. The wind speed on Saturn is 500 meters per second, which is more than the speed of sound in the air on Earth. The stormiest planet in the solar system is Neptune. Here the wind speed can reach up to 600 meters per second. [17] [18] [19]

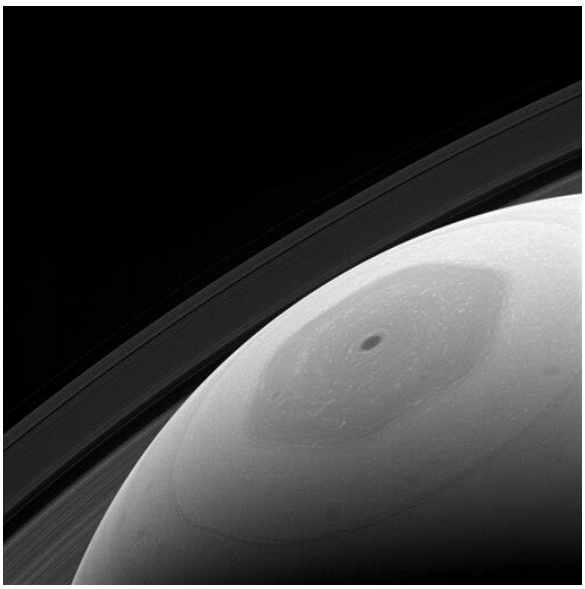


Figure 4: Hexagon of Saturn. If you inspect the first image, you can see it there too.

The most striking feature of Saturn is its rings. That's probably not even debatable. But Saturn has another such structure. It's called Saturn's Hexagon. A hexagon among so many circles. You have to acknowledge it, it is unique. This hexagon is made of clouds. It was discovered by David Godfrey in 1987 based on the pictures taken by NASA's Voyager program in 1981. But what is the mystery behind the origin of such uniqueness?

No one knows exactly how it originated. There are some hypotheses, but let's not delve into them any deeper. (Once again? Good hoax you say?) [20] [21] [22] [23] [24] [25]

The next planet is Uranus. It is an ice giant and the third largest planet in the solar system by volume.

And if Pluto is not considered a planet, then the farthest known planet from the sun is Neptune, the planet after Uranus, and the third largest in the solar system by mass. It is also an ice giant. As the name suggests, the planets are mostly made of ice. However, the ice we are familiar with our daily life, that is, the solid state of water, is not what meant here. Then is it crystal methamphetamine that we mean here? For those who do not know, methamphetamine is a kind of drug that is also called ice in slang. Fortunately, that is not meant either. Or should I say unfortunately? [26] [27] [28] [29] [30]

I have heard that drug users and drug dealers are very desperate for drugs. So many innovative new methods they invent for drug trafficking! And if this is taken into account, then it should be reckoned that it is unfortunate that ice doesn't mean methamphetamine here. Because if ice meant methamphetamine, that is, if the ice giants were made of methamphetamine and if this news reached our drug users, then it would turn out that we would not need the scientists who are researching to go to Mars anymore. Let alone Mars, our brave drug users would make rocket themselves and venture into Uranus and Neptune.

But our misfortune! So what we really mean by ice?

Objects made of materials such as silicate, iron, nickel are called rocks. On the other hand, objects made of materials such as water, methane, ammonia, hydrogen sulfide, etc. are called ice. Here, however, it does not matter what state these materials are in, i.e. gaseous, liquid or solid. In whichever state it is, if it is made of water, methane, ammonia, hydrogen sulfide, etc., it is ice. [31]

The structure of Uranus and Neptune are almost the same. The main constituent material is ice. There is a rocky core, surrounded by ice and a hydrogen or helium shield on the outside. The ice in the middle that is mentioned here is not ice in the usual sense, but fluid. Fluids made of water, methane and ammonia. [31] [32] [33] If Pluto is not considered a planet, Neptune is the coldest planet in the solar

system (in average temperature). Although Neptune's position is much farther from the sun than Uranus, the lowest temperature among planets, -224 degrees Celsius, has been recorded on Uranus.

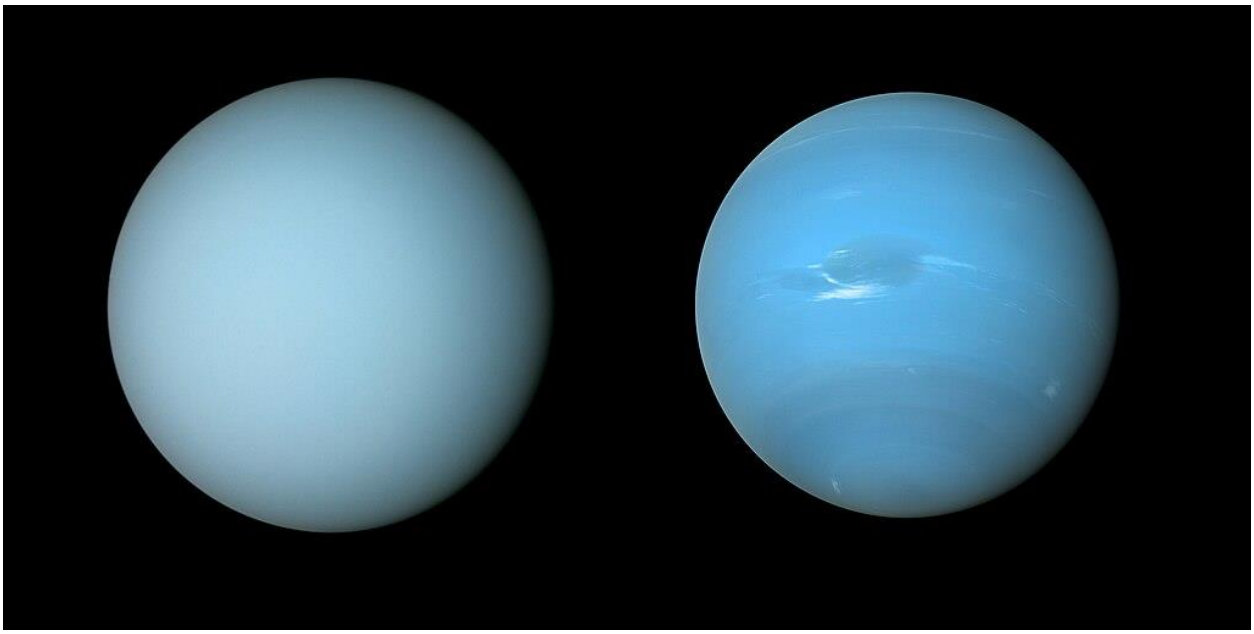


Figure 5: Uranus (left) and Neptune (right), rather same in appearance and health.

Once again, if Pluto is not considered a planet, the difference between the maximum and minimum distances from the sun of any planet is the highest in the case of Uranus. And Neptune is the slowest rotating planet around the sun in the solar system. It takes 164.8 Earth years to complete one year in Neptune. The second planet with the roundest orbit is also Neptune. And Neptune is the only planet in the solar system that cannot be seen with the naked eye. [26] [28] [29] [35]

So these four were the giant planets. None of them have a solid surface. Big storms reign these planets. Maybe it rains diamond instead of water inside them. [36] [37] [38] (Has the word not reached the ears of the diamond traders yet?)

Each giant planet has a common feature, they radiate more heat than they get from the sun. Where does this extra heat come from? It is assumed that when the planets were born, they were very hot and they are still radiating that heat. As giant planets are very large, a lot of heat accumulates inside them that they cannot radiate. That heat is now slowly being radiated. The other planets cannot radiate as much heat as the giant planets. The heat that is radiated from the interior of the earth is only one ten thousandth of the heat that the earth receives from the sun. [27] [39] [40] [41]

Again, Uranus radiates much less heat than the other giant planets. But it is not clear why Uranus does so. One hypothesis is that in the beginning Uranus collided with a large object and as a result Uranus is in this state now. Saturn's heat radiation is also somewhat anomalous. If the heat inside Saturn at birth was the source of Saturn's radiated heat, then Saturn should radiate much less heat than it does now. But in fact, Saturn radiates relatively much heat. It is assumed that the separation of helium from hydrogen inside Saturn is the source of this extra heat. [27] [41]

The next object after Neptune is Pluto. Although I never said it's a planet, I think it should be added here. How much trouble we have gone through with one Pluto? Some say it's not a planet and some say it is. How much truth is in the first sentence of this paragraph? Pluto's orbit is so elliptical that at one stage of orbiting the sun, Pluto goes closer to the sun than Neptune. Then does Pluto remain the object after Neptune? No, Neptune becomes the object after Pluto. [42]

Figure 6: Image of Pluto captured by the New Horizons Spacecraft. You can see the heart shaped fragment too. You can visit the link to a high-resolution version of this beautiful image for a better experience.

(Pluto is a colorful world, black, orange, white, variety at its limit perhaps!) One of Pluto's unique features is its heart-shaped glacier. (Although it is difficult to understand why people mean heart by this shape) There are some big mountains on Pluto, mountains made of ice, and here ice means real ice, solid form of water. The biggest mountains are two to three kilometers high. And maybe it snows on Pluto. There are dunes here, not dunes of sand, dunes of frozen methene. There may be an ocean under Pluto's solid surface. [43] [44] [45]

Let's get a little closer to the earth now. Mars, the farthest rocky planet from the sun. The surface is covered with rust, so it looks red, hence another name, 'Red Planet'. If Pluto is not considered a planet, this planet with half the diameter of the earth is the smallest planet after Mercury in the solar system. The surface is marked with the highest mountains, dead volcanoes, large canyons, and ice caps in the polar regions. Marsquakes and seasons are day to day events on Mars. The largest sandstorms in the solar system occur on Mars. There is no existence of the canals that were said to have been created by intelligent creatures on Mars in the early twentieth century. [54] But there is the largest canyon in the solar system, more than 4,800 kilometers long. Here the length of the day is almost equal to that of the

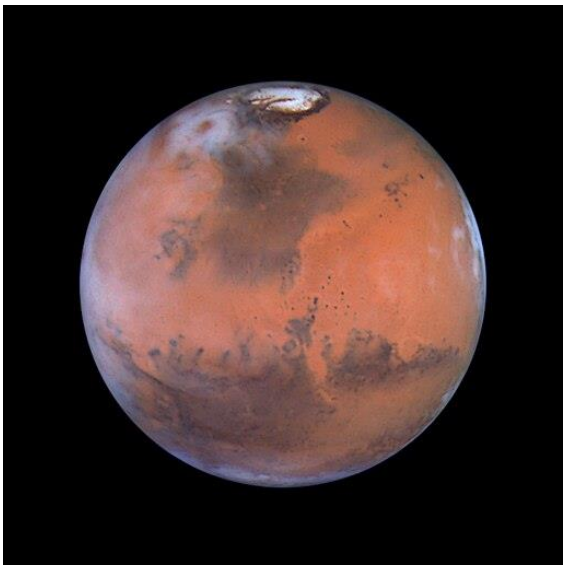


Figure 7: Mars, captured by Hubble Space Telescope. The polar ice cap of Mars is visible in this image.

earth, 24.6 hours and the year is 687 earth days. Olympus Mons on Mars is the highest peak in the solar system, almost 22 kilometers high. Almost two and a half times Mount Everest. Who knows, maybe Olympus Mons is saying now, "A glimpse of my high head makes the Himalayan peak bow." But there is a bad news for Mons, maybe, a mountain on a planetoid, Vesta, Rheasilvia, is higher than Olympus Mons. [48] [49] [50] [51] [52]

The sky of Mars is hazy and red to the human eye. There was a lot of water on the planet. But that bluish past has been lost long ago. Let me mention it, water is not in fact colorless. It has its own color and it is bluish, but very light. [46] [47] [53]

And now, from Mars, we drift too close to the sun. Mercury, if Pluto is not considered a planet, is the smallest planet in the solar system. This planet, which is closest to the sun, is slightly larger than our moon. The sun's light here can be up to seven times as bright as on Earth. If Pluto is not considered a planet, the most elliptical orbit of all the planets belong to Mercury. Its orbit is so elliptical that when the planet is closest to the sun, the sun is almost twice as bright than it is when it is farthest. [55] The difference in temperature between day and night here is almost 600 degrees Celsius, which is the highest in the solar system. The fastest moving planet in orbit around the sun is also Mercury, 47.36 kilometers per second! Mercury is a planet, but it is geologically dead. That is, there is no new formation of mountains, volcanic eruptions or other geological activities here. The interesting thing is that even though Pluto is not a planet, it is not geologically dead! However, new research says Mercury is not really dead. [57] [58] [60]

Figure 8: Largest volcano of the solar system, Olympus Mons

Among the planets, Mercury has the second highest density. Compared to other planets in the solar system, Mercury has the highest amount of iron per unit volume in ratio. The ratio of iron and silicate in other rocky planets is only half as much, roughly. And if Pluto is not considered a planet, the most deviated planet from the ecliptic is Mercury. The planet is 7 degrees tilted from the ecliptic. In terms of average distance, Mercury is the closest planet to all other planets of solar system, I repeat, the closest planet to any planets of the solar system is mercury in terms of average distance. [56] [59] [63]

The closest planet to Earth is Venus, the brightest object in the sky after the sun and the moon. In English, it is called Venus, the only planet named after a female deity, that is, a goddess. Venus comes

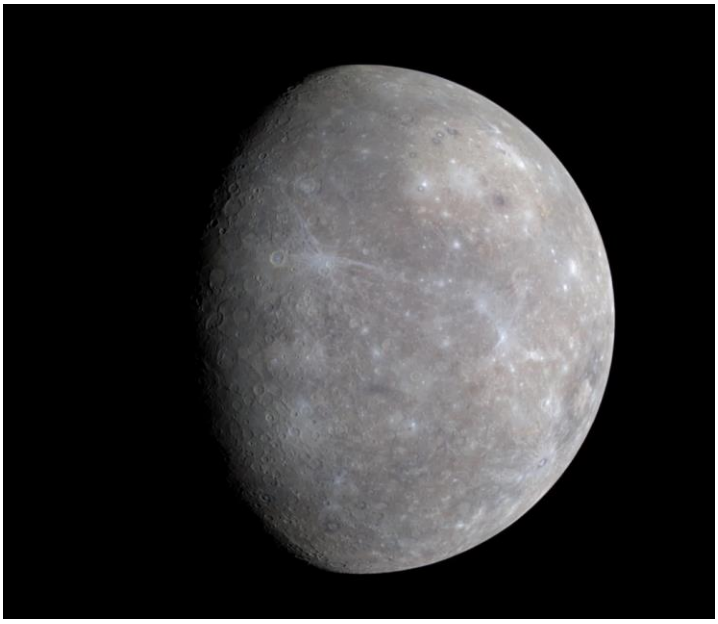


Figure 9: Mercury, the closest planet to Sun. Captured in 2008 by Messenger Probe.

the closest, closest in terms of distance, to earth than any other planet. However, Venus comes this close to Earth only for a short time. At other times, Mercury is the closest to Earth, but Mercury never comes as close to Earth as Venus. In terms of size and density, Venus is almost like Earth, so the planet is sometimes called Earth's twin brother (or sister? Since it is named after a goddess). And Venus is the first planet where humans have sent a spacecraft, Mariner 2. [61] [62] [63]

The surface temperature of Venus is the highest among the planets in the solar system, so high that it can melt lead. In fact the temperature of Mercury, the closest planet to the sun, is lower than that. The reason for this abnormal feature of Venus is the greenhouse gas present in its atmosphere. The atmosphere of Venus is mainly composed of carbon dioxide. And here clouds are formed by sulfuric acid. The atmosphere is so dense that it is very difficult to see the surface of Venus from satellites. [64] Very little sunlight can penetrate the atmosphere and reach the surface. The pressure of the atmosphere on the planet is almost 100 times that of the Earth's atmosphere. That is, 100 elephants per square meter. In this extreme situation, the robots sent to the surface of Venus cannot function properly. Many of the ten landers sent by the Soviets did not work. And those that functioned were alive for a maximum of only two hours. The pictures sent by them show that the sky of Venus is a little yellowish. There are more than 85,000 volcanoes here and research says that there are still active volcanoes on Venus. [65] [66] [61] [62]

Figure 10: Venus, the closest planet to earth. This image was captured in 1974 by Mariner 10.

Venus orbits the sun in such a way that when the distance from Earth to Venus is the lowest, only and nearly one side of Venus is visible from Earth, much like our moon. The gravitational interaction of Earth, Venus and the sun and the atmosphere of Venus are responsible for this. Venus has another feature that is like our moon. The moon has phases of waxing and waning, that is, at first there is a small crescent slice of the moon is visible, as the days go by the size of the slice increases until the full moon is visible. From after the event of the full moon, in the next day a slice of the moon becomes dark, i.e. it goes invisible. And as days goes by, the size of that slice increases until the whole moon disappears and a new moon is born in the new month. The same is true for Venus when seen from Earth. At first it is a little slice, then it gradually grows to a full Venus and then it fades away slice by slice until

Venus disappears from the sky. It takes about thirty days, or a month, to complete this cycle for the moon. And Venus takes 584 days. The famous scientist Galileo Galilei was the first to observe this phenomenon with his telescope. This activity of Venus proves Copernicus's heliocentric solar system. [61]

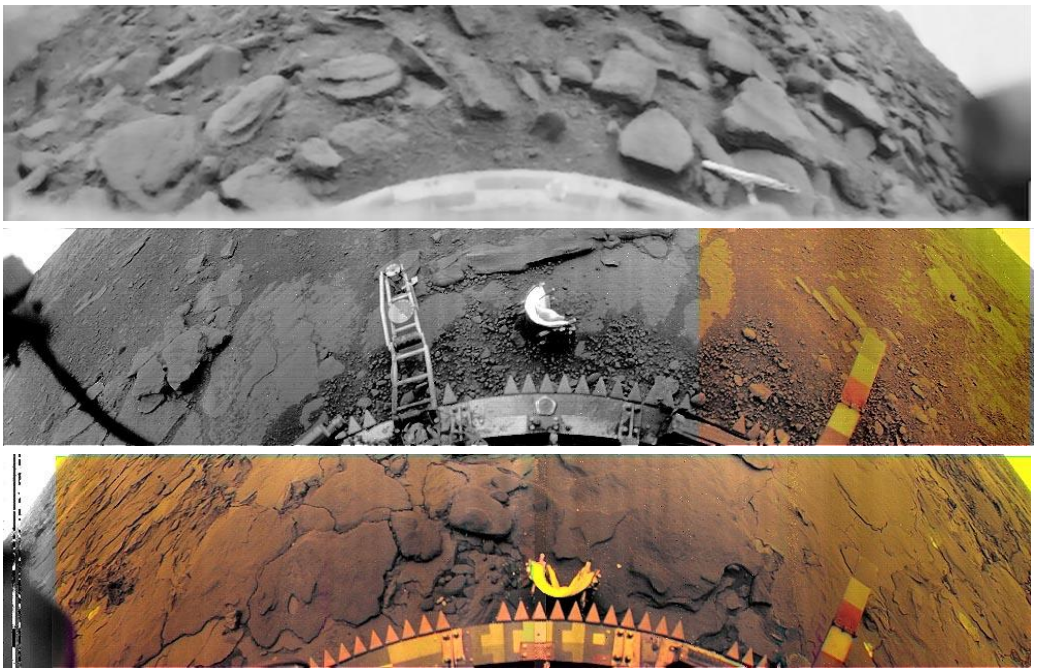


Figure 11: Surface of Venus from Venera-9, Venera - 13 and Venera-14 (top to bottom) sent by the Soviets. These images were captured respectively in 1975, 1981, 1982.

In the solar system, the planets usually orbit the sun from one direction, counter-clockwise, but Venus does it from the opposite direction, clockwise. As a result, the sun rises in the west and sets in the east here. However, it is a matter of concern how much of the sun can be seen through this massive atmosphere of Venus. There is another planet in the solar system that orbits the sun this way, Uranus, the first planet discovered by humans after the prehistoric era. The reason for such behavior of these two planets is unknown. It is assumed that they are in this state due to collisions with various objects. However, there are some other hypotheses too. [61] [27] [67] [89]

Currently, Venus has no satellites. However, one hypothesis says that in the beginning, even if Venus had no satellites, at some point a satellite was born due to a collision with an object. However, later, when the direction of Venus's orbit around the sun was reversed by another collision, the satellite collided with Venus due to the tidal force and was destroyed. [68]

The rotational speed of Venus on its own axis is the lowest among the planets, it takes 243 days for the planet to complete a full rotation on its own axis. That is, one day on Venus is equal to 243 Earth days. The surprising thing is that it takes 225 days to go around the sun once on Venus! That is, the day is longer than the year here! However, Venus is not the only planet where the day is longer than the year. There is another planet where this happens, Mercury. [67] [35]

It takes about 88 days for Mercury complete its orbit around the sun. And it takes about 59 days to rotate on its own axis. But one day on Mercury is equal to 176 days. How is that possible? Actually, the old tidal force is pulling the strings here too. The tidal force between the sun and Mercury. As the tidal

force between the Earth and the moon causes only one side of the moon to be visible from the Earth, in the same manner, it increases the length of the day in Mercury. [55]

Figure 12: Different phases of Venus as seen from Earth.

The moon rotates around its own axis once every time it orbits the Earth. As a result, only one side of the moon can be seen from the Earth. Mercury, in the same way, rotates around its own axis three times for every two times it orbits the sun. As a result, it takes about 88×2 or 59×3 or almost 176 days from one sunrise to the next on Mercury. If Mercury rotated around its own axis once every time it orbited the sun, that is, if it was tidally locked, then the sun would have only been visible from one side of the planet, and the other side would always be in darkness. It was previously thought that Mercury was tidally locked with the sun, like our moon, but this was proved wrong later. [69]

However, a strange phenomenon, strange, bizarre, peculiar or whatever you designate it, occurs on Mercury. Mercury is not like Venus; the sun rises in the east and sets in the west here. That is, if you stand on the surface of the planet, you would see the sun moving from east to west. Normal, right? But from certain places at certain times on Mercury, you can observe the sun reverse its course from east to west, that is, the sun suddenly starts to move from west to east! After a while, the sun again reverses its course back to east to west. And again, from some places here, you can see the sun rise in the east for a short time and then set and rise again! [55] [70] [71]

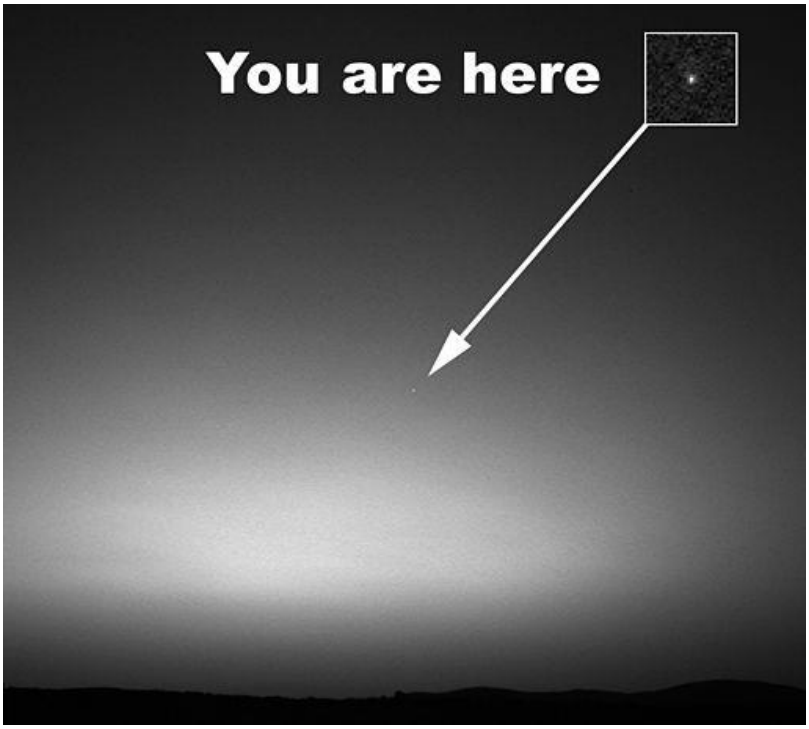


Figure 13: Earth captured by Mars exploration rover Spirit.

Another feature of Venus and Mercury is that there is a thin ring of dust in their orbits, the path they follow around the sun, just like Saturn's rings. It is believed that these rings are the remnants of the accretion disks from which Mercury and Venus were born. [72] [73]

Finally, the Earth; the largest rocky planet in the solar system. The density of this planet is also the highest among the planets in the solar system. After Venus and

Neptune, it has the most circular orbit round the sun. [35] The only planet in the solar system whose English name is not derived from Greek or Roman mythology. And the only place we know where life exists, not just exists but thrives. [74] [75]

In the account of mass, the most abundant element on Earth is iron (about 32%) and the second most abundant element is oxygen (about 30%).[76] Earth is the only planet in the solar system that has liquid water on its surface. One of the main reasons for the existence of life on our planet is probably its rocky composition. The presence of large amount of water and a reasonable distance from the sun are also among the major triggers. [74] [75]

It is believed that liquid water once existed on the surface of Mars, just like Earth, but that water was lost in space due to the solar wind, the influence of various particles from the sun and other reasons. Then why didn't the water on Earth disappear? One stimulus why the water on Earth did not disappear is that the Earth has a strong magnetic field that protects the Earth from the solar wind. When the magnetic field collides with the solar wind, a light show is created, which is called aurora or northern lights. This light show can usually be seen from the regions near the two poles of the Earth. [77] [78]

The interior of the Earth contains iron and nickel. When the Earth rotates, these metals also rotate and create a magnetic field. This magnetic field has two poles, one north pole and one south pole. Determining these poles with a compass, we determine direction. So if there is a strong magnet nearby the compass, the compass cannot determine the direction accurately. [83] [80]

Figure 14: Aurora Borealis captured from Lapland, Finland.

Earth has to fill three conditions to produce this magnetic field. The presence of a fluid in the interior of the planet that can carry electric current, the rotation of the planet and the circulation of that fluid. In the absence of any one of these, no magnetic field is generated. [79] [81] [82]

If so, then from where does the magnetic field in planets like Jupiter or Saturn arise? In fact, among the planets in the solar system, Jupiter's magnetic field is the most powerful. As evidence, auroras can be seen in the sky of Jupiter and Saturn. [86] They are mainly composed of hydrogen and helium. Hydrogen and helium are not electrically conductive, are they?

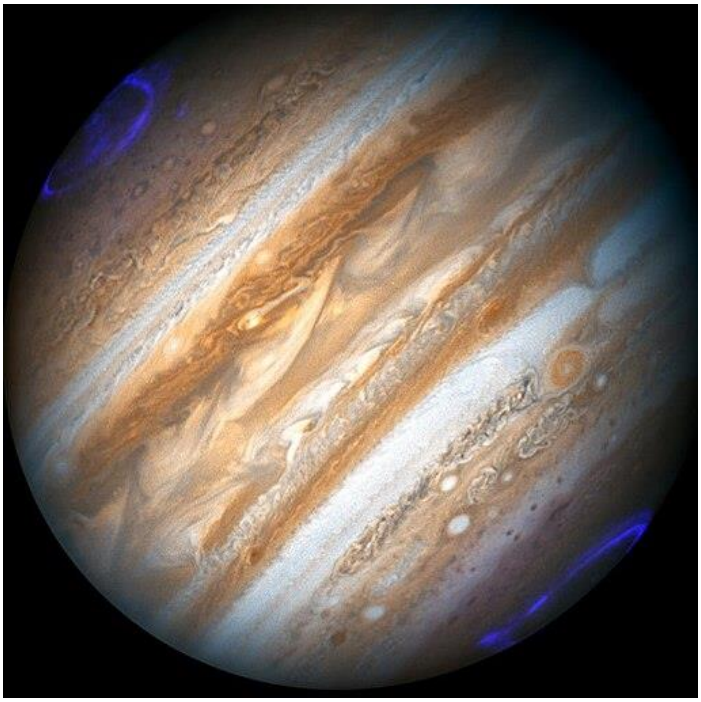


Figure 15: Jupitar's Aurora, captured by Hubble Space Telescope.

Actually, in the interior of these planets, hydrogen behaves like liquid metal under high pressure. In this state, hydrogen is called metallic hydrogen. And this metallic hydrogen gives birth to the magnetic field. The interesting thing is that Ganymede, the largest satellite in the solar system, also has its own magnetic field. But ironically, even some planets do not have it! [84] [85]

A year is 365 days on Earth. If there was no change of seasons, every year would feel dull for sure. How fortunate it is that there is a change of seasons on Earth and we get date juice in winter and mango, berry, jackfruit, lychee in summer. This change of seasons happens because the Earth cannot stand straight.

Imagine there is a cultural program going on somewhere. Some people have decided to present a dance as the concluding performance of the program. The dance would be rather of a bizarre kind, one person will stand in the middle of the stage with both hands spread out and spin like a top. And centering that person, eight more people will move in a circle. And those eight people too will spin with both hands spread out like a top, while orbiting the person on the center. So, when it was time, they began the dance as planned. Some of those who were dancing did not have a good sleep the previous night. As a result, they could not stand straight, they were wobbling here and there. So after a while of enduring that dance, some of the audience began getting annoyed. It was a silly dance first of all, and on top of that, their mouths were watering recalling the promise of biryani packets destribution at the end of the program. Why is that silly dance not ending? Then two men from the audience went mad and decided to stop the dance by any means. That way, they would not have to endure the dance anymore and get the biryani packets quickly.

So the two of them went up on stage. Let me mention here, those who are dancing are sumo-type people and these two men who are going to attack are built like San-bushman people. Anyway, the attackers went and attacked, one went for one dancer and the other one went for another dancer. But as I said before, those who are dancing are sumo-type people and the attackers are Bushman-type. How could they match the sumos? So when they went and pushed the sumo-type dancers, they themselves went flying in the air and fell outside the stage. They had only one thought in their minds then, “oh, I’ve just broken my limbs in the greed of eating biryani few minutes earlier. And if I had waited a few moments, I would have gotten the biryani anyway. Perhaps that’s why they say, grasp all lose all.”

So this was the situation of the attackers. And what about those who were dancing?

The two who were attacked by the Bushmen-sized people had some impact on them. One of them turned upside down from the push, that is, he is now spinning with his feet up and his head down. And the other one, who had more strength in his body, did not turn upside down but fell to the ground. He is

now spinning like a rolling egg. How committed they are to the dance! Even after all this, they did not stop dancing!

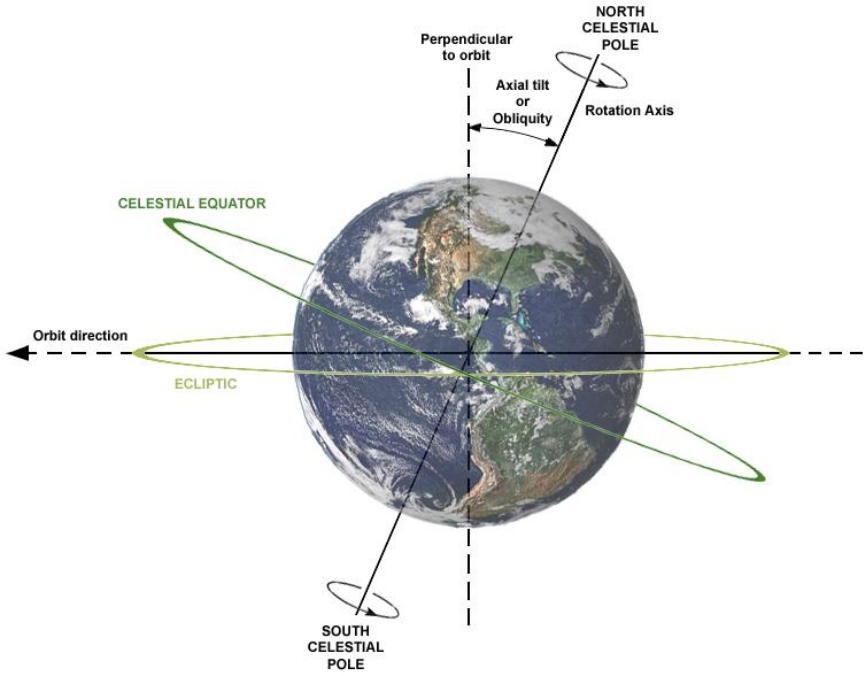


Figure 16: The tilt of Earth.

Now, try to imagine, the Earth, spinning around the sun. Now draw an imaginary line between the sun and the center of the Earth. And draw another vertical line to that line. Now draw another imaginary line through the north and south poles of the Earth. This line makes an angle of 23.93 degrees with the vertical line to the line through the center of the Earth and the sun. If the Earth were straight, the magnitude of this angle would be zero. That is, the Earth is not standing straight. Therefore, the Earth is like those dancers who did not sleep at night and are now wobbling here and there while performing the dance. In English, this is called "Axial Tilt". But there is an advantage of this wobbling. Because of this, each side of the Earth leans more towards the sun at different times. And because of this leaning, the seasons cycle is seen on Earth! [90]

I said a little earlier, Venus and Uranus are two planets where the sun rises in the west and sets in the east. Now I'm saying, the sun rises in the east and sets in the west too like other planets on these two planets. But how so?

Venus is like that dancer who has turned upside down after being pushed. And Uranus is like that one who has fallen down on the ground. But it would be wrong to say that Uranus has fallen down straight. Uranus's condition is something like this, from the waist to the head is in contact with the ground and from the waist to the feet is slightly higher than the ground. That is, Uranus also has its lower side, i.e. legs upward and head downward. So now, if the feet are considered as the head, then Uranus and Venus are spinning in the opposite direction, that is, the sun is rising in the west. And if the head is considered as the head, then Uranus and Venus are spinning in the right direction, that is, the sun is rising in the east. [91]

Since Venus has turned upside down and its feet and head look the same, (isn't it obvious? Its like a sphere) it seems that Venus is standing straight, that is, Venus doesn't bother with season change. But what about Uranus? Its head, i.e. upside has tilted almost 90 degrees. [87] [88] The earth's head is 23.93 degrees tilted, and that slight tilt results in six seasons in Bangladesh. What kind of situation does Uranus's almost 90-degree tilt create there? Can you imagine? From these aspects, Mercury is the

folksiest of planets, or perhaps in some people's opinion, the dullest planet. Because its tilt is only 0.034 degrees. That is, the straightest planet standing is Mercury. [35] [92] [93]

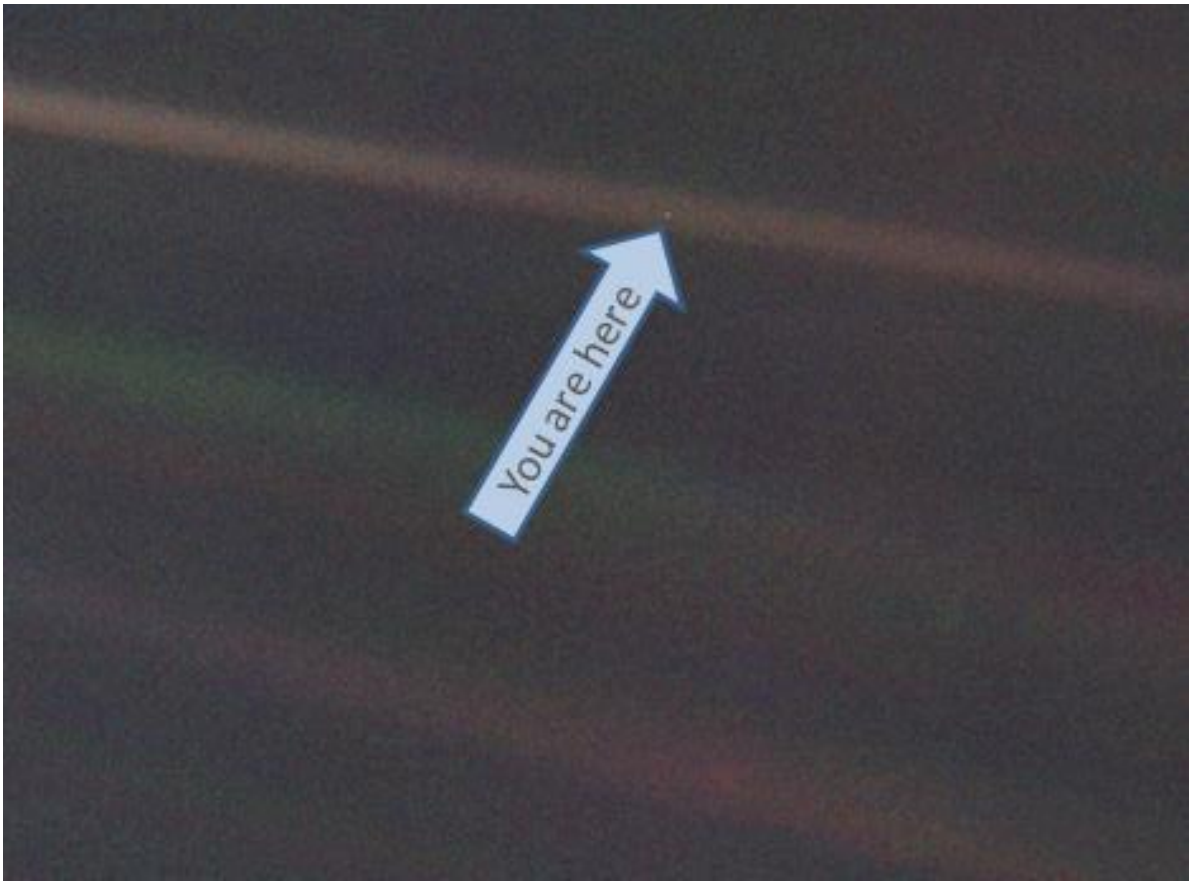


Figure 17: Our Earth; In 1990, form nearly the distance of 6 billion kilometers, Voyager-1 took this beautiful image of planet Earth. This is a quite renowned image known as 'The pale blue dot'.

1. Overview | Planets – NASA Solar System Exploration; Overview | Planets – NASA Solar System Exploration (archive.org);
2. Overview | Jupiter – NASA Solar System Exploration; Overview | Jupiter – NASA Solar System Exploration (archive.org);
3. In Depth | Jupiter – NASA Solar System Exploration; In Depth | Jupiter – NASA Solar System Exploration (archive.org);
4. Williams, David R. (December 23, 2021). "Jupiter Fact Sheet". NASA. Retrieved October 13, 2017. Jupiter Fact Sheet | Ghostarchive;
5. Kruijer, Thomas S.; Burkhardt, Christoph; Budde, Gerrit; Kleine, Thorsten (June 2017). "Age of Jupiter inferred from the distinct genetics and formation times of meteorites". *Proceedings of the National Academy of Sciences*. **114** (26): 6712–6716. Bibcode:2017PNAS..114.6712K. doi:10.1073/pnas.1704461114. PMC 5495263. PMID 28607079.

6. Sun Fact Sheet (nasa.gov); Sun Fact Sheet | Ghostarchive;
7. Zubritsky, Elizabeth. "Jupiter's Youthful Travels Redefined Solar System". NASA. Retrieved 4 November 2015.; Wayback Machine (archive.org);
8. (PDF) The Grand Tack model: a critical review (researchgate.net); September 2014; Proceedings of the International Astronomical Union 9(S310); DOI:10.1017/S1743921314008254; Raymond, Sean & Morbidelli, Alessandro. (2014). The Grand Tack model: a critical review. Proceedings of the International Astronomical Union. 9.
9. Watanabe, Susan, ed. (February 25, 2006). "Surprising Jupiter: Busy Galileo spacecraft showed jovian system is full of surprises". NASA. Retrieved February 20, 2007.; Wayback Machine (archive.org);
10. Britannica, The Editors of Encyclopaedia. "Great Red Spot". Encyclopedia Britannica, 21 Jul. 2023, https://www.britannica.com/place/Great-Red-Spot. Accessed 6 September 2023.
11. What Is a Barycenter? | NASA Space Place – NASA Science for Kids; What Is a Barycenter? | NASA Space Place – NASA Science for Kids (archive.org);
12. MacDougal, Douglas W. (December 16, 2012). *Newton's Gravity: An Introductory Guide to the Mechanics of the Universe*. Springer New York. p. 199. ISBN 978-1-4614-5444-1.
13. Petit, J.-M.; Morbidelli, A.; Chambers, J. (2001). "The Primordial Excitation and Clearing of the Asteroid Belt" (PDF). *Icarus*. **153** (2): 338–347. Bibcode:2001Icar..153..338P. doi:10.1006/icar.2001.6702. Archived (PDF) from the original on February 21, 2007. Retrieved March 22, 2007.
14. "How Asteroids and Comets Formed ." Lucent Library of Science and Technology: Comets and Asteroids. . *Encyclopedia.com.* 23 Aug. 2023
15. [0903.3305] Jupiter - friend or foe? II: the Centaurs (arxiv.org); Jonti Horner, Barrie W Jones; https://doi.org/10.48550/arXiv.0903.3305; Jupiter - friend or foe? II: the Centaurs - NASA/ADS (harvard.edu);
16. Owen, Tobias Chant. "Jupiter". Encyclopedia Britannica, 5 Sep. 2023, https://www.britannica.com/place/Jupiter-planet. Accessed 6 September 2023.
17. Giant Planets: Atmospheres (colorado.edu); Giant Planets: Atmospheres (archive.org);
18. Saturn Fact Sheet (nasa.gov); Saturn Fact Sheet | Ghostarchive;
19. Hamilton, Calvin J. (1997). "Voyager Saturn Science Summary". Solarviews. Archived from the original on 26 September 2011. Retrieved 5 July 2007.
20. Godfrey, D.A. (1988). "A hexagonal feature around Saturn's north pole". *Icarus*. **76** (2): 335–356. Bibcode:1988Icar...76..335G. doi:10.1016/0019-1035(88)90075-9.
21. A Vexing Hexagon – NASA Solar System Exploration; A Vexing Hexagon – NASA Solar System Exploration (archive.org);
22. Saturn's Hexagon in Motion | Saturn – NASA Solar System Exploration; Saturn's Hexagon in Motion | Saturn – NASA Solar System Exploration (archive.org);
23. NASA - The Puzzling Hexagon; Wayback Machine (archive.org);
24. In Depth | Saturn – NASA Solar System Exploration; In Depth | Saturn – NASA Solar System Exploration (archive.org);
25. Marley, Mark , Buratti, Bonnie and Hubbard, William B.. "Saturn". Encyclopedia Britannica, 8 Aug. 2023, https://www.britannica.com/place/Saturn-planet. Accessed 7 September 2023.;

26. Miner, Ellis D.. "Neptune". Encyclopedia Britannica, 23 Aug. 2023, https://www.britannica.com/place/Neptune-planet. Accessed 8 September 2023.
27. Ingersoll, Andrew P.. "Uranus". Encyclopedia Britannica, 19 Aug. 2023, https://www.britannica.com/place/Uranus-planet. Accessed 8 September 2023.
28. In Depth | Uranus – NASA Solar System Exploration; In Depth | Uranus – NASA Solar System Exploration (archive.org);
29. In Depth | Neptune – NASA Solar System Exploration; In Depth | Neptune – NASA Solar System Exploration (archive.org);
30. Examining Ice Giants With NASA's Webb Telescope | NASA; Examining Ice Giants With NASA's Webb Telescope | NASA (archive.org);
31. Comparative models of Uranus and Neptune | Semantic Scholar; M. Podokal, A. Weizman and M. Marley; Podolak, Morris et al. "Comparative models of Uranus and Neptune." *Planetary and Space Science* 43 (1995): 1517-1522.;
32. Jack J. Lissauer; David J. Stevenson (2006). "Formation of Giant Planets" (PDF). *NASA Ames Research Center; California Institute of Technology*. Archived from the original (PDF) on 2009-02-26. Retrieved 2006-01-16.
33. The atmospheres of Uranus and Neptune | Semantic Scholar; Jonathan Lunine; Lunine, Jonathan I.. "The atmospheres of Uranus and Neptune." *Annual Review of Astronomy and Astrophysics* 31 (1993): 217-263.;
34. Suomi, V.E.; Limaye, S.S.; Johnson, D.R. (1991). "High Winds of Neptune: A possible mechanism". *Science*. **251** (4996): 929–32. Bibcode:1991Sci...251..929S. doi:10.1126/science.251.4996.929. PMID 17847386. S2CID 46419483.
35. Planetary Fact Sheet (nasa.gov); Planetary Fact Sheet | Ghostarchive;
36. 'Diamond rain' on giant icy planets could be more common than previously thought | SLAC National Accelerator Laboratory (stanford.edu); 'Diamond rain' on giant icy planets could be more common than previously thought | SLAC National Accelerator Laboratory (archive.org);
37. Diamond drizzle forecast for Saturn and Jupiter | Nature; McKee, M. Diamond drizzle forecast for Saturn and Jupiter. Nature (2013). https://doi.org/10.1038/nature.2013.13925;
38. 11.3 Atmospheres of the Giant Planets - Astronomy 2e | OpenStax; ISBN-13: 978-1-951693-50-3; page 393-403;
39. Patrick G. J. Irwin (2009). *Giant Planets of Our Solar System: Atmospheres, Composition, and Structure 2nd edition*. Springer. p. 4-5. ISBN 978-3-642-09888-8.
40. The Outer Planets: Giant Planets: Interiors (colorado.edu); The Outer Planets: Giant Planets: Interiors (archive.org);
41. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-951693-50-3; page 363-364;
42. "Pluto to become most distant planet". JPL/NASA. January 28, 1999. Archived from the original on September 2, 2010. Retrieved January 16, 2011.
43. New Horizons Spacecraft Displays Pluto's Big Heart | NASA; New Horizons Spacecraft Displays Pluto's Big Heart | NASA (archive.org);
44. 10 Cool Things We Learned About Pluto | NASA; 10 Cool Things We Learned About Pluto | NASA (archive.org);
45. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-951693-50-3; page 430-431;
46. Carr, Michael H. , Belton, Michael J.S. and Malin, Michael C.. "Mars". Encyclopedia Britannica, 7 Sep. 2023, https://www.britannica.com/place/Mars-planet. Accessed 8 September 2023.

47. In Depth | Mars – NASA Solar System Exploration; In Depth | Mars – NASA Solar System Exploration (archive.org);
48. Plescia, J. B. (2004). "Morphometric Properties of Martian Volcanoes". *J. Geophys. Res.* **109** (E3): E03003. Bibcode:2004JGRE..109.3003P. doi:10.1029/2002JE002031.
49. Vega, P. (11 October 2011). "New View of Vesta Mountain From NASA's Dawn Mission". *Jet Propulsion Lab's Dawn mission web site*. NASA. Archived from the original on 22 October 2011. Retrieved 29 March 2012.
50. 10 Things: Grand Canyons – NASA Solar System Exploration; 10 Things: Grand Canyons – NASA Solar System Exploration (archive.org);
51. 10 Things: Massive Dust Storm on Mars – NASA Solar System Exploration; 10 Things: Massive Dust Storm on Mars – NASA Solar System Exploration (archive.org);
52. *Philips, Tony (16 July 2001). "Planet Gobbling Dust Storms". Science @ NASA. Archived from the original on 13 June 2006. Retrieved 7 June 2006.* This article incorporates text from this source, which is in the public domain.
53. Braun, Charles L.; Smirnov, Sergei N. (1993), "Why is water blue?" (PDF), *Journal of Chemical Education*, **70** (8): 612–614, Bibcode:1993JChEd..70..612B, doi:10.1021/ed070p612
54. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-951693-50-3; page 338;
55. Chapman, Clark R.. "Mercury". Encyclopedia Britannica, 9 Aug. 2023, https://www.britannica.com/place/Mercury-planet. Accessed 9 September 2023.
56. Strom, Robert G.; Sprague, Ann L. (2003). *Exploring Mercury: the iron planet*. Springer. ISBN 978-1-85233-731-5. Page 44 and 52;
57. Small, Shrinking Mercury Is a Planetary Space Oddity (nationalgeographic.com); Small, Shrinking Mercury Is a Planetary Space Oddity (archive.org);
58. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-951693-50-3; page 430;
59. In Depth | Mercury – NASA Solar System Exploration; In Depth | Mercury – NASA Solar System Exploration (archive.org);
60. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-951693-50-3; page 232-233;
61. Squyres, Steven W.. "Venus". Encyclopedia Britannica, 25 Aug. 2023, https://www.britannica.com/place/Venus-planet. Accessed 9 September 2023.
62. In Depth | Venus – NASA Solar System Exploration; In Depth | Venus – NASA Solar System Exploration (archive.org);
63. "Venus is not Earth's closest neighbor". *Physics Today*. AIP Publishing. 12 March 2019. doi:10.1063/pt.6.3.20190312a. ISSN 1945-0699. S2CID 241077611.
64. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-951693-50-3; page 312;
65. Evidence of an Active Volcano on Venus | Science Mission Directorate (nasa.gov); Evidence of an Active Volcano on Venus | Science Mission Directorate (archive.org);
66. Hahn, Rebecca M.; Byrne, Paul K. (April 2023). "A Morphological and Spatial Analysis of Volcanoes on Venus". *Journal of Geophysical Research: Planets*. **128** (4): e2023JE007753. Bibcode:2023JGRE..12807753H. doi:10.1029/2023JE007753. S2CID 257745255.
67. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-951693-50-3; page 316;
68. Musser, George (10 October 2006). "Double Impact May Explain Why Venus Has No Moon". *Scientific American*. Archived from the original on 26 September 2007. Retrieved 7 January 2016.
69. Professor Robert B. Laughlin, Department of Physics, Stanford University; Professor Robert B. Laughlin, Department of Physics, Stanford University (archive.org);
70. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-951693-50-3; page 297-300;

71. Strom, Robert G.; Sprague, Ann L. (2003). *Exploring Mercury: the iron planet*. Springer. ISBN 978-1-85233-731-5. Page 36-45;
72. Garner, Rob (12 March 2019). "What Scientists Found After Sifting Through Dust in the Solar System". *NASA*. Retrieved 21 January 2023. What Scientists Found After Sifting Through Dust in the Solar System | NASA (archive.org);
73. Rehm, Jeremy (15 April 2021). "Parker Solar Probe Captures First Complete View of Venus Orbital Dust Ring". *JHUAPL*. Retrieved 21 January 2023. Parker Solar Probe Captures First Complete View of Venus Orbital Dust Ring | Johns Hopkins University Applied Physics Laboratory (archive.org)
74. In Depth | Earth – NASA Solar System Exploration; In Depth | Earth – NASA Solar System Exploration (archive.org);
75. Jeanloz, Raymond , Lunine, Jonathan I. and Chapman, Clark R.. "Earth". Encyclopedia Britannica, 6 Sep. 2023, https://www.britannica.com/place/Earth. Accessed 10 September 2023.
76. Morgan, J. W.; Anders, E. (1980). "Chemical composition of Earth, Venus, and Mercury". *Proceedings of the National Academy of Sciences*. **77** (12): 6973–6977. Bibcode:1980PNAS...77.6973M. doi:10.1073/pnas.77.12.6973. PMC 350422. PMID 16592930.
77. "Planetary Shields: Magnetospheres". NASA. Retrieved 5 January 2020.; Planetary Shields: Magnetospheres (archive.org);
78. Aurora: Illuminating the Sun-Earth Connection | NASA; Aurora: Illuminating the Sun-Earth Connection | NASA (archive.org);
79. E. Pallé (2010). *The Earth as a Distant Planet: A Rosetta Stone for the Search of Earth-Like Worlds (Astronomy and Astrophysics Library)*. Berlin: Springer. pp. 316–317. ISBN 978-1-4419-1683-9. Retrieved 17 July 2010.
80. C:/Documents and Settings/Owner/My Documents/EM PROJECT/DYNAMO THEORY.dvi (harvard.edu); DYNAMO THEORY: THE PROBLEM OF THE GEODYNAMO; RAMANDEEP GILL; March 21, 2006; Wayback Machine (archive.org);
81. McPherron, Robert L.. "geomagnetic field". Encyclopedia Britannica, 1 Sep. 2023, https://www.britannica.com/science/geomagnetic-field. Accessed 10 September 2023.
82. Britannica, The Editors of Encyclopaedia. "dynamo theory". Encyclopedia Britannica, 3 Dec. 2018, https://www.britannica.com/science/dynamo-theory. Accessed 10 September 2023.
83. Manners, Joy (2000). *Static Fields and Potentials*. USA: CRC Press. p. 148. ISBN 978-0-7503-0718-5.
84. Metallic Interiors and Magnetic Fields of Jupiter and Saturn - NASA/ADS (harvard.edu); R. Smoluchowski; Princeton University, Princeton, New Jersey; Received 1971 January 5; DOI: 10.1086/150971; Astrophysical Journal, vol. 166, p.435; June 1971;;
85. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-951693-50-3; page 362, 364-365, 385;
86. 05-solar-system-jupiters-aurora.pdf (nasa.gov); Wayback Machine (archive.org);
87. Planet-Shifting Collision Shaped Uranus' "Rolling" Rotation | NASA; Planet-Shifting Collision Shaped Uranus' "Rolling" Rotation | NASA (archive.org);
88. Solar System Exploration: Science & Technology: Science Features: Weather, Weather, Everywhere? (nasa.gov); Solar System Exploration: Science & Technology: Science Features: Weather, Weather, Everywhere? (archive.org);
89. Britannica, The Editors of Encyclopaedia. "retrograde motion". Encyclopedia Britannica, 15 Feb. 2018, https://www.britannica.com/science/retrograde-motion. Accessed 10 September 2023.

90. Britannica, The Editors of Encyclopaedia. "season". Encyclopedia Britannica, 9 Sep. 2023, https://www.britannica.com/science/season. Accessed 10 September 2023.
91. Explanatory supplement to the Astronomical almanac : a revision to the Explanatory supplement to the astronomical ephemeris and the American ephemeris and nautical almanac : Seidelmann, P. Kenneth : Free Download, Borrow, and Streaming : Internet Archive; page 384;
92. Correia, A. C. M.; Laskar, J. (2003). "Long-term evolution of the spin of Venus: II. numerical simulations" (PDF). *Icarus*. **163** (1): 24–45. Bibcode:2003Icar..163...24C. doi:10.1016/S0019-1035(03)00043-5;
93. Correia, Alexandre C. M.; Laskar, Jacques; de Surgy, Olivier Néron (May 2003). "Long-term evolution of the spin of Venus I. theory" (PDF). *Icarus*. **163** (1): 1–23. Bibcode:2003Icar..163....1C. doi:10.1016/S0019-1035(03)00042-3;

Companion Keeper?

The Crescent Moon
Amy Lowell

Slipping softly through the sky
Little horned, happy moon,
Can you hear me up so high?
Will you come down soon?
On my nursery window-sill
Will you stay your steady flight?
And then float away with me
Through the summer night?
Little rocking, sailing moon,
Do you hear me shout — Ahoy!
Just a little nearer, moon,
To please a little boy.

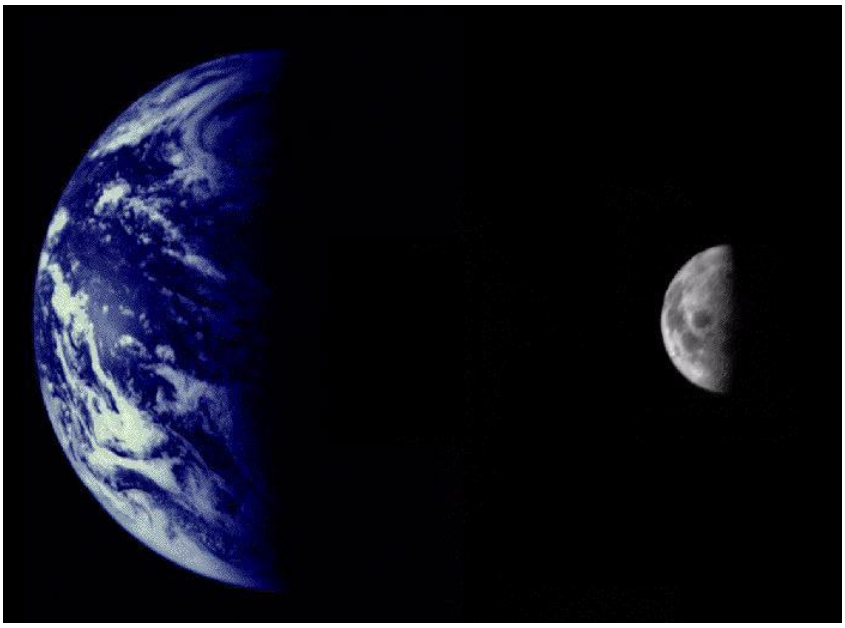


Figure 1: Earth and Moon in a single frame; Captured by Mariner 10 in 1976 from a distance of 2.6 million kilometers.

My boy, my boy! Halt there, halt this instant! You wanna doom us all to an apocalypse? How in the world would you be pleased if the moon gets nearer? What's your age boy? I think you are going to grow into one of those psychopaths. Grow into? I beg pardon. You are a psychopath, thinking of killing us all sending the moon away from the earth or causing a collusion between them. But let me point something out boy, if that happens, not even you would be able to enjoy our doom with that crooked brain of yours. You too would die with us, at least that's what today's technology says. Nursery's no place for you. Someone, send him immediately to a mental asylum. Hurry!

I often hear a thing, the moon is tidally locked with the earth. Before we know what tidal locking is, we should know what tidal force is.

Imagine, three pillows, from the moon, respectively 100, 200 and 300 kilometers away. (Let me clear something out here, for this example, people usually use three balls instead of pillows. But in Bangla, balls and force have the same spelling. So, sometimes it gets confusing. Since, I wrote this book in Bangla and now I'm translating it, I'll stick to pillows. And verily, sticking to pillows is one of the best experiences people have in their whole life. Who wouldn't want to stick to pillows? Oh, and another thing, some people may jam their brains wondering whether the pillows are made of silk-cotton, ***Bombax ceiba*** or tree-cotton, ***Gossypium arboretum.*** You pals, as long as their masses are same, it doesn't matter. But since I am sticking to these pillows, they better be made of silk-cotton.) Now, the three pillows, under the influence of gravity, are rushing towards the moon. According to Newton's law of gravity, every mass-bearing object attracts another mass-bearing object, this attraction is called the gravitational force. As the distance increases, the amount of gravitational force decreases. As a result, the pillow 100 kilometers away from the moon has the most force on it, and the pillow 300 kilometers away from the

moon has the least force on it. Now, the one with less force on it, speeds towards the moon slowest. And the one with more force on it, its speeds towards the moon faster.

You have set up a camera on the second pillow, i.e. the pillow in the middle. When the pillows are freely, under the influence of gravity, falling towards the moon, you are sitting in the control room, chewing betel nut and the live footage of the camera is playing on a huge monitor. What do you think you will see?

You will see, the pillow 100 kilometers away from the moon is going forward, but the pillow 300 kilometers away from the moon is going backward!

When you look out of the train window, you feel that you are stationary, and the trees outside are moving. Now if the train line is next to a road, you will be able to see the cars on the road as well. Now imagine, there are two cars on the road. One is an old antique, black smoke emitting car and the other is a modern hybrid. The black smoke emitting car, the hybrid and the train all have the same destination, say Kyrgyzstan. Now the train, the black smoke emitting car and the modern hybrid car have begun their journey from the same place, say Kazakhstan, at the same time. (Why would they do so? How in the world am I supposed to know?) Remember, the black smoke emitting car has the lowest speed and the hybrid has the highest speed. You are a passenger on the train. Within a few moments of the start of the journey, you will see that the hybrid has left the train behind and gone far ahead. And the black smoke emitting car will fall behind the train due to its slow speed. As time goes on, the black smoke emitting car will fall further behind the train and the hybrid will go further ahead of the train. Now, as a train passenger, what will you see? Since the train passengers feel that the train is stationary and the outside world is moving, you will feel that the black smoke emitting car is not going forward, but going backward, the train is stationary, and the hybrid is going forward.

And in the same way, in the case of our pillows, you will see that the pillow, farthest from moon, is going further back, the second pillow is stationary, and pillow, closest to the moon, is going forward. And as a result, like the car and the train, the distance between the three pillows will also gradually increase.

Now, imagine, the pillow 100 kilometers away from the moon is connected to the pillow 200 kilometers away by an elastic, and the pillow 200 kilometers away is connected to the pillow 300 kilometers away by another elastic. Now what will happen? As time goes on, the two elastics will stretch more and more. Why? Because, as I said before, as time goes on, the distance between the pillows will increase. And as the distance increases, the elastics will have to stretch, right?

Now let's return to the earth and the moon. The moon pulls the earth (it seems, the moon really wants to get a little closer to the earth), the side that is closer to the moon feels more force, and the other side feels less. Let me clear something out first.

The moon is supposed to fall on the earth due to the attraction of gravity. But it doesn't. The reason is, the moon is orbiting around the earth. The moon is rushing towards the earth, but at the same time, the moon is also crossing a considerable distance sideways.

If you fire a bullet from a gun, it will go forward and at the same time it will fall downwards. Eventually, the bullet will fall to the ground. Now, the earth is round. So, if the speed of the bullet is very high, then the bullet will not get time to fall to the ground because, the earth is round. The bullet will keep falling downwards, but the ground will keep bending. It's like, you raised your hand to catch a fly, but by the

time your hand touched the place where the fly was idling, the fly flew away somewhere else. (Now don't you start shooting bullets here and there being motivated by this example.)

The same thing happens with the moon. The moon keeps falling towards the earth, but at the same time, the moon crosses a certain distance sideways, which causes the moon to always miss the earth. The earth is round!

Now the interesting thing is, as the moon is constantly being pulled towards the earth by the earth's gravitational force, the earth is also being pulled towards the moon by the moon's gravitational force. But, like before, because of the sideways motion, the moon and the earth never collide.

Now, since the earth is constantly moving towards the moon, we can go back to the pillows. When the pillows were moving towards the moon, the distance between the pillows was increasing, and the same will happen with the earth. The side of the earth that is closer to the moon and the opposite side will have an increased distance between them. Now stop for a while and think, if you stretch an elastic, its length increases but its width decreases. So, when the moon pulls the earth, the earth's vertical length will increase, but its horizontal length will decrease. That is, if one side expands, the other side contracts. That is, the earth will change its shape from circular to slightly elliptical. [1] [2]

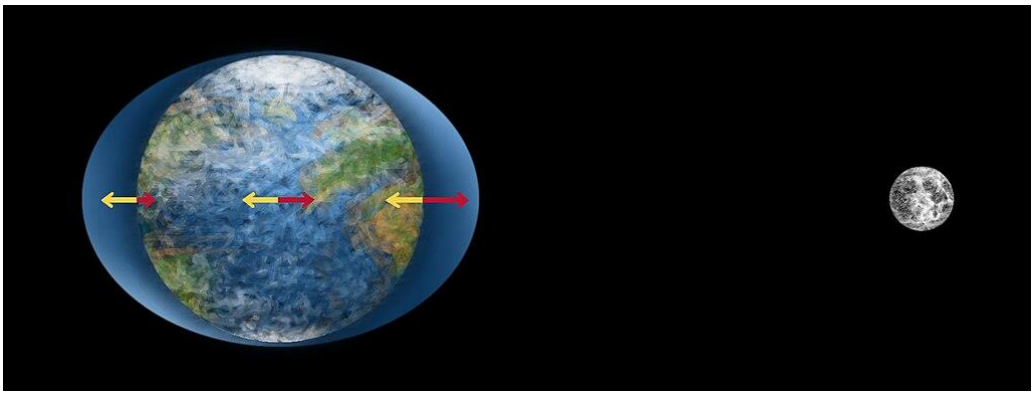


Figure 2: How the moon's attraction influences tides on earth

Now, let's discuss a bit about tides. Due to the moon's attraction, water accumulates on the the part of the earth that is closer to the moon. Water also accumulates on the opposite side of that part too. This is called high tide. And the water that accumulates comes from the middle of the earth. As a result, the amount of water in the middle decreases. This is called low tide. If you think a little, you will realize that during high and low tides, the earth takes a slightly elliptical shape. And it has already been discussed how the earth takes an elliptical shape! That is, the moon is causing the earth to contract and expand, which is creating the tides. So, in this case, the gravitational force is called the tidal force or the tide force.

Not only in the case of the moon or the earth, but in any case, where such contraction and expansion occur, the gravitational force is called the tidal force. However, I will clarify one thing, the tides on the earth are not only due to the moon's attraction, rather the sun's attraction and the earth's rotation also play a role. But the moons effect is the greatest. And another thing to keep in mind, water is fluid. So, water easily takes an elliptical shape. And the ground is solid, so even if the solid part of earth takes a elliptical shape, it is negligible. So we can't perceive it with our eyes. If the tidal force is too high, it can tear a planet into halves! [3] [4] [5](For a better explanation see: [6] [7])

So, we learned what the tidal force is. Now let's move on to tidal locking.

Figure 3: The moon, as we see it from earth

Do you know how the moon was formed? The most popular hypothesis is the giant-impact hypothesis. Here, the earth is considered as a truck and a small planet named Theia is considered as a stray wonderer. So the event goes is like this:

One day, Theia goes astray and collides with the earth while wandering around. In this collision, some part of the earth also breaks off. Some part of Theia and some part of the earth combine to form a ring-like structure. Later, this ring becomes a molten sphere. And this sphere becomes the moon under the influence of the earth's gravity. So, at first, the moon was a molten sphere, and its rotation around its own axis was also very high. But, due to the tidal force, the shape of the moon became more elliptical. But the moon's rotation around its own axis created a problem. [8] [9]

Imagine, AB and CD are two lines that cross the middle of the moon. When point A or B is close to the earth, the moon expands along AB and contracts along CD. Then the moon rotates around its own axis, and when point C or D comes close to the earth, the moon expands along CD and contracts along AB.

Thus, due to contraction and expansion, a lot of energy is lost. And when energy is lost, the rotation speed of the moon on its own axis decreases. As the speed decreases, at one point, a situation arises where, the time it takes for the moon to rotate once on its own axis, and the time it takes for the moon to orbit around the earth are the same. What happens as a result?

As a result, any point on the moon, be it A, or B, or C, or D, will always face the earth, that is, stay close to the earth. And since the moon's orbit is almost circular, only one point of the moon can be seen from the earth, not the others. And when the time it takes to rotate once on its own axis and the time it takes to orbit are the same, it is called tidal locking and the moon is said to be tidally locked to the earth. [10](see [10] for a nice animation too)

Because of tidal locking, we only see one side of the moon, not the other. Until 1959, the other side of the moon remained unseen. Finally, thanks to the Soviet Luna program, we got to see the picture of the opposite side of the moon. [11]

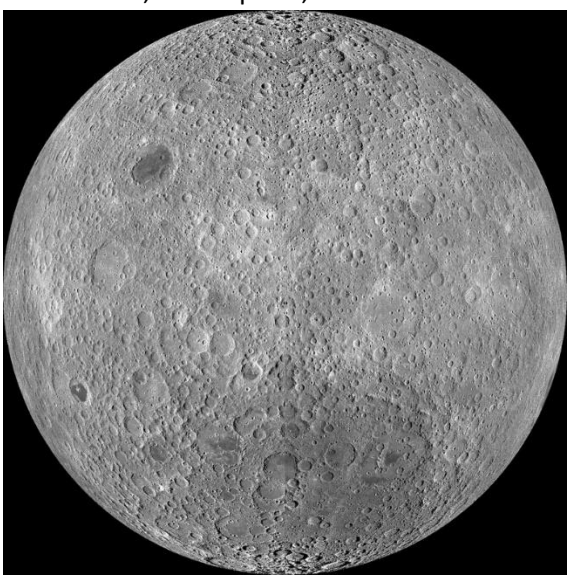


Figure 4: The dark side of the moon as seen from Reconnaissance Orbiter

A while earlier, I was talking about the energy loss of the moon. And before that, I said that tides are created because of the moon (the moon contracting on one side first and then expanding on the same side later). Now some may wonder, if the moon loses energy due to the earth's tidal force, why doesn't the earth lose energy due to the moon's tidal force? The earth does contract and expand due to moon's tidal force. Actually, the earth too loses energy. And because of this energy loss, the earth's rotation speed on its own axis is decreasing. As a result, the length of the day is increasing slightly day by day. Also, the energy that the earth is losing is accumulating on the moon. As a result, the moon is gradually moving away from the earth slightly. However, the increase in the length of the day and the amount of the moon moving away are very small. So, there is no reason to worry for now. [10] [12] [13]

If the earth and the moon survive and everything continues like this, then after about 50 billion years, the earth will be tidally locked with the moon. Then, only the people on one side of the earth will be able see the moon. The people on the other side will not be able to see the moon just going to the rooftop of their house, they will have to travel half the earth to the other side of the earth. And if you want to experience something like this right now, then you can go to Pluto. Because Pluto and its moon Charon are tidally locked with each other. [10] [14] [15]

Actually, tidal locking is a rather common phenomenon. There are many examples of it in our solar system. For example, the Galilean moons with Jupiter; the two moons of Mars, Phobos and Deimos; the moon Proteus and Triton with Neptune; etc. By the way, have you wondered if the earth becomes tidally locked with the moon, what will happen to the tides on earth? Think about it. [10] [16] [17] [18] [19] (Ah, it feels great to make people worry)

So, it has been some heavy facts going on for a while. There will be some more but, before that, let's lighten up a bit.

During my childhood, when the electricity went out at night, we used to go out for a walk. A few things used to catch my eyes. The flickering bioluminescent fireflies, the star-filled sky, the half-eaten moon above my head and the lights in the government quarters in the distance thanks to the generator (sorry, I couldn't help but say that. Actually, the light is not the issue. The issue is, light on means fan on!).

Nowadays, I often hear from my parents that in the past (when they were kids) the mosquito nuisance was much less than now. I don't remember, how the mosquito nuisance when I was a kid. But it really feels good to look at the moon without the mosquito nuisance. So, when I used to look at the moon as a child, my parents would show me the moon and say, "The old lady on the moon turning the spinning wheel." I would look carefully and see, yes, that's right. On the silver moon (actually, I think it's ghee or white. But, the mystery writers use the word silver so much with the moon that my fingers couldn't help but write silver) there is something black, like an old lady, bending over. Maybe she is turning the spinning wheel. Then I wondered, what does the old lady on the moon do with so much thread? Now that I've blemished both of my eyes, I can't see the moon like that time anymore. And how many days have I not gone out at night?

Anyway, when I was a child, I read in a book that there is a sea on the moon, called the Sea of Tranquillity. I told this to one of my sisters, and was I excited! She did not believe me, of course. Nearby was another sister of mine. She said, "There's no water on the moon. How could there exist a sea?" They were older than me by quite a bit. So, I accepted their words, there is no sea on the moon. But, there

was another reason for accepting it. The book from which I read there is a sea on the moon, also included the information that there are eleven planets in the solar system!

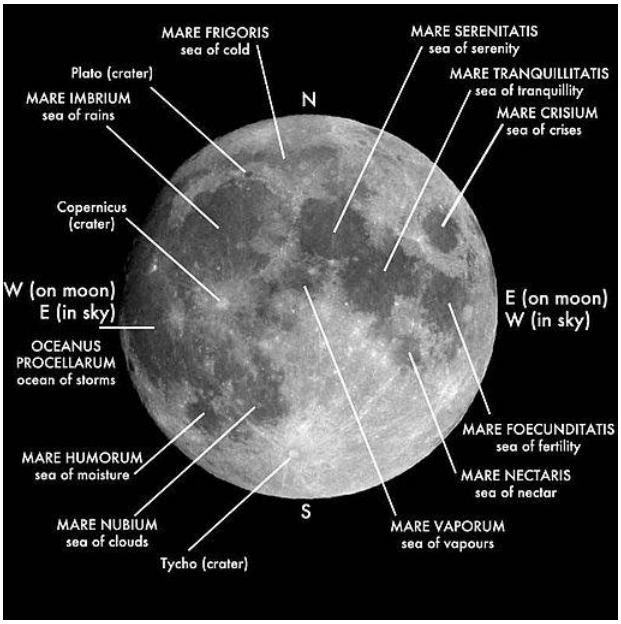


Figure 5: Some Mares of the moon

Years passed by after that. I didn't even remember when was the last time I wondered whether there was a sea on the moon or not. Suddenly one day I wondered about it. Is there really a sea on the moon? I started digging. And I found out, there really is a sea on the moon! Not one, but many. These seas are called lunar maria. And they have all kinds of strange names. The Sea of Tranquillity is one of them. Even more amazing, almost sixteen percent of the moon's surface is covered in these seas. I was even more surprised to learn that, when humans first set foot on the moon, they landed on the Sea of Tranquillity! I mean, they can land wherever they want to, but what's the point of landing in the water?

Well, actually, a long time ago, some parts of the moon for several causes got covered by lava, which later turned into basalt. Now basalt reflects less light than other parts of the moon. As a result, the basalt-covered part looks black from earth. The Greek philosopher Plutarch (AD 46 - after AD 119) thought, these are actually seas. Days passed by in its usual pace. Some said, the black spots are seas, and the white part is land. Again, some said the opposite. Finally, one day Kepler wrote to Galileo, "The dark spots are seas, the bright parts are land." Kepler and Galileo agreed on the black spots to be seas. Because of their popularity, it became popular that, the black spots are actually seas. Later, Johannes Hevelius named the black parts Mare. Which means sea in Latin. [20] [21] [22]

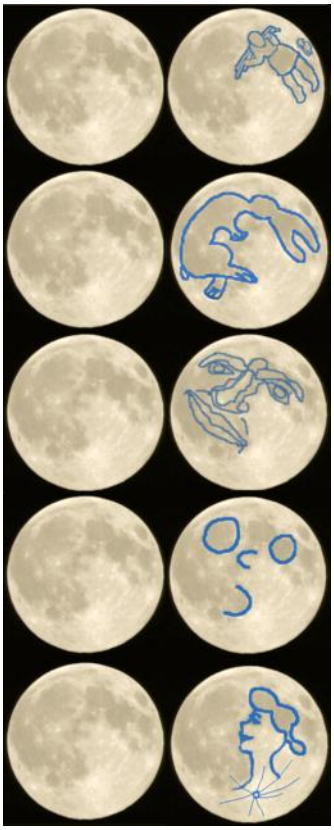


Figure 6: Different shapes people from different parts of the world see on the moon

And we imagine that black part as, "the old lady on the moon turning the spinning wheel." We Bengalis (at least me and my family members) see an old lady, others see a face, they call it "the man in the moon" in English. In addition, people in different parts of the world see various things like frogs, rabbits, etc. [23]

A confession: I knew what Sea of Tranquility was before I learned, when man first set foot on the moon they landed on the Sea of Tranquility. But in an attempt to dramatize the writing, I wrote above that I learned what the Sea of Tranquility was, later.

By the way, do you know that there are earthquakes on the moon too? Although it is called moonquake. Moonquakes occur for different reasons.

Meteorite impacts, extreme temperature differences between day and night causing contraction-expansion of the moon rocks (just as rail lines bend in strong sunlight) and the tension that results from the tidal force of the earth on the moon causes these moonquakes. [24] [25]

The largest moon in the solar system is Ganymede. It is Jupiter's moon. Then comes Titan, Saturn's moon. Then in order are Callisto, Io and our moon, the Moon. The surprising thing is that the first two moons, that is, Ganymede and Titan are so big that they are in fact bigger than Mercury! But the cruel joke of fate, Mercury is now a planet but Ganymede and Titan are satellites. [26] [27]

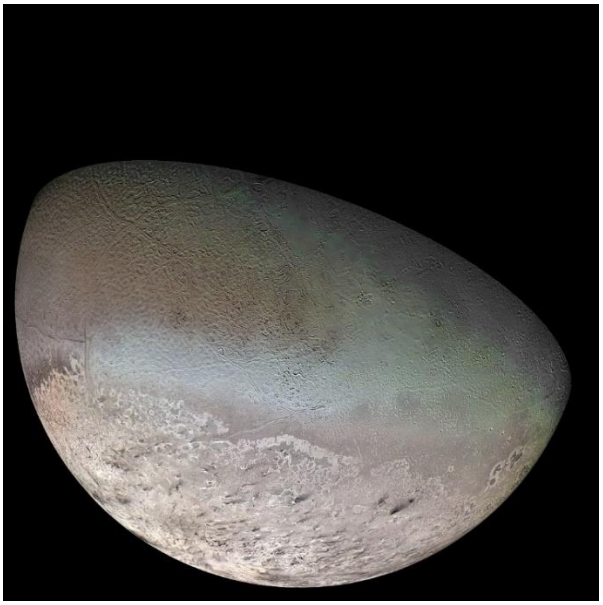


Figure 7: Neptune's moon Triton. This image was captured by Voyager 2

As a disk forms around a star and planets form from that disk, a circumplanetary disk may also forms around the planets. Later from this circumplanetary disk, satellites are born. Again, sometimes, when a celestial object passes by a planet, the planet takes possession of that celestial object by its gravity. The object then orbits around the planet as a satellite. However, the orbits of the satellites that are born through such robbery are much more elliptical, tilted, and far away from the parent planet. And in some cases, their rotation direction is opposite to the rotation direction of the parent planet. For example, Neptune's moon Triton. [28] [29] [30] [31] [32]

However, Earth's moon is an exception. The characteristics of our moon's orbit are similar to those of the satellites that are formed from the circumplanetary disk. Close to the earth, circular orbit, and the direction of rotation is also towards the earths. But the moon of the earth came from a wayward wonderer who was passing by, as explained earlier. Then why such an exception? Remember, Theia hit the earth. As a result, some parts of Theia and some parts of the earth mixed up, forming a ring, which later became a sphere and that sphere later became the moon that we see today. [33] [10] But Neptune never managed to touch Triton, where earth did touch Theia. It only managed to tie Triton in an orbit around itself by the trance of its gravity. It's like fasting. You can cook amazing food with your extraordinary cooking skills, but you can't taste those food before the time of iftar. Nah, the analogy didn't work out well because of iftar.

But wait! Let's get back to tidal force again. Because of the tidal force, where our moon is moving away from the earth, Triton there, is gradually getting closer to Neptune! In this way, if Triton continues to get closer to Neptune, two things can happen. Due to the extra tidal force the satellite will have to endure for getting closer to Neptune, Triton can break into pieces. And the second thing that can happen is that Triton will hit Neptune. [34] [35] [36] That is, Neptune will have the opportunity to break the fast! Hopefully, the second event will happen, and my analogy will have its fulfilment.

Now let's talk about some other moons in the solar system. Galileo saw four moons of Jupiter with his telescope. So they are called Galilean moons. Unlike the parent planet, none of them are gaseous, they

are all rocky. The largest one is called Ganymede. [37] [38] It is bigger than the planet Mercury. Ganymede has its own magnetic field. And since it poses a magnetic field, it is assumed that its interior is semi-melted. However, Jupiter's tidal force plays a big role behind its magnetic field. It is believed that there is liquid water inside this satellite. Possibly, more water than all the oceans combined on Earth! [39] [40] [41] [42] [43]

Figure 8: The four Galilean moons. From the left, Io, Europa, Ganymede and Callisto

Let's visit Callisto, shall we? Callisto is the farthest of the Galilean moons from Jupiter. It is a fairly featureless, very cold and ice-covered satellite. The oldest landscape in the solar system is Callisto's landscape. Which means, not of any planets but of a satellite is the oldest! [44] [45] [46]

Next we will go to Europa. Europa is the smallest in size among the Galilean moons. Its surface is covered with ice. However, it is believed that under this ice, there is a lot of liquid water. [47] [48]

And there is one more of these moons, Io. Jupiter's closest Galilean moon. In size, a little bigger than our moon. Among the moons of the solar system, it has the highest density. And being close to Jupiter, it endures high amount of tidal force. Unable to withstand the pull and push of this extra tidal force, Io causes a lot of volcanic eruptions. On Io, there are more than four hundred active volcanoes. Due to the substances emitted from these volcanoes, various colors can be seen on Io. Yellow, red, black, white, green. Also, there are some mountains on Io, some of them have a height higher than Mount Everest! Can you imagine that a satellite has higher mountains than our planet! [49] [50] [51] [52] [53]

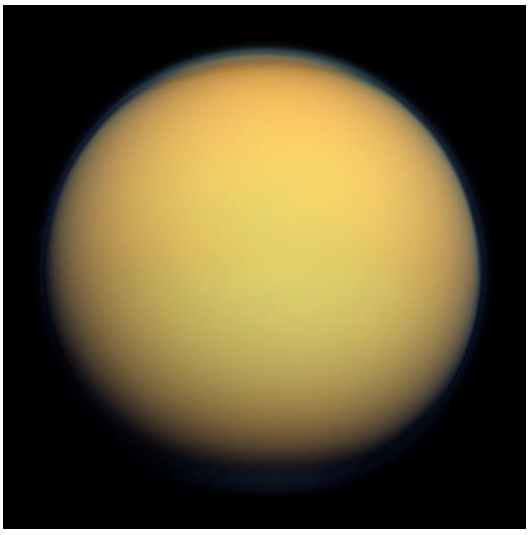


Figure 9: Saturn's moon Titan, from the eye of Cassini spacecraft

The most feature-rich moon of Saturn is probably Titan. Being larger than Mercury, it is the second largest satellite in the solar system and the first discovered moon after Galileo's moons. The temperature on Titan's surface is -179 degrees Celsius. This temperature is so low that methane (at normal pressure, methane turns into gas at −161.5 °C) stays in liquid state here. It is the only object in the solar system other than Earth that has liquid on its surface. The air pressure here is 1.6 bar, which is higher

than the air pressure on Earth. In the picture taken by the robot sent to Titan, it can be seen that the color of Titan's sky is orange. Titan is such a place where there is wind, clouds and rain. Where rivers flow into lakes and seas. There are dunes here, but not of sand. Rather, they are formed of hydrocarbons. Like Earth, most of its atmosphere is composed of nitrogen. However, on Titan, water does not flow in the rivers, waves of water don't break on the lake shores, and when it rains, what fall from the sky isn't water. On Titan, liquid methane flows in rivers, waves of liquid methene breaks on the lake shores, liquid methane vaporizes and form clouds and rain fall from the clouds as streams of liquid methene. Much like Earth, isn't it? Only it's H_2O on Earth, and CH_4 on Titan. Maybe there are volcanic eruptions here, but not of molten lava like Earth, but of liquid water. [54] [55] [56]

Figure 10: The surface of Titan. Image credit goes to Huygens probe

I wanted to discuss about one last of these moons. But before we do so, let me talk a little bit about Saturn's ring. When it's the matter of Saturn, the first thing that comes to one's mind is Saturn's ring. But did you know that Jupiter, Uranus and Neptune too have rings? However, they are not as clear or beautiful as Saturn's ring (of course, who am I to define beauty?).

So, what is this ring (planetary ring) thing actually? And how are they born?

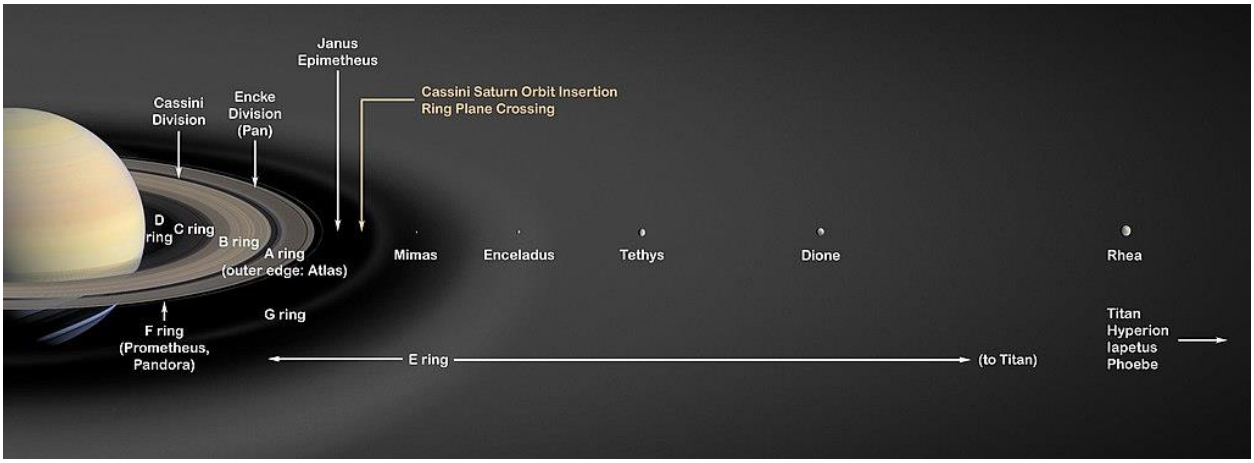


Figure 11: Different parts of the ring of Saturn

Rings are quite similar to moons. When lot of dust particles and small objects orbit a planet, they form rings. And there are several theories on how these rings are born. It may be that the circumplanetary disk that forms around a planet did not become a moon due to the tidal force of the planet and remained as a ring. Or it may be that a moon of a planet has broken into pieces due to a collision with another object and created a ring around the planet. Or, just because of the excessive tidal force of a planet, a moon of that planet has broken into pieces and later formed the ring. And this third event may happen in the case of Neptune, if Neptune does not get the opportunity to break its fast. Although

Neptune has a small ring, if Triton fall to pieces, maybe a beautiful (again, who am I to define beauty?) ring will be created around Neptune. [57] [58]

A planet's ring can be divided into several parts. The main part of our Saturn's ring is 70,000 kilometers wide. But the thickness is only 20 meters! There is a ring on the outside of Saturn called E Ring. This ring is different from Saturn's other rings. It is much wider. Its thickness is much more, almost 2000 kilometers. And its composition is different, small pieces of ice. Ice, frozen water. But from where and how is this ice here? [59] [65]

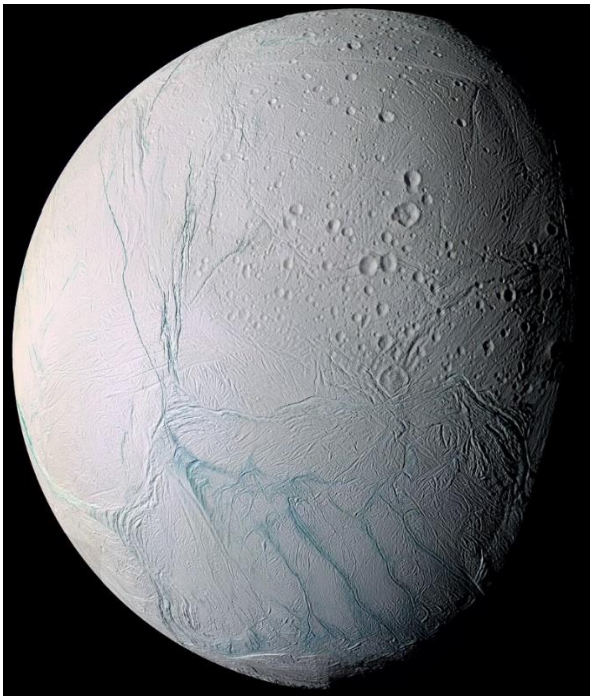


Figure 12: Enceladus, captured by Cassini spacecraft

I said, I would discuss about another moon. The name of this moon is Enceladus, the sixth largest moon of Saturn. And this Enceladus has some cryovolcanoes. Cryovolcano or ice volcano is a type of volcano where instead of magma, water, ammonia or methane substances are erupted. And the environment around a cryovolcano is very cold. From these cryovolcanoes, steam, hydrogen and various metals erupts, like fountains. Some of this emitted substance fall back on the surface of Enceladus. But the remaining part manages to escape into space. And these escaped parts form one of Saturn's rings, called the E ring! [60] [61] [62] [63] [64]

Does our moon seem pale compared to these extraordinary moons? Do you know, every planet in the solar system that has moons, has more than one moon? Earth is the only planet whose number of moons is one. [66]

The largest moon in the solar system is Ganymede. But compared to Jupiter, Ganymede's size is nothing. In comparison to the parent planet, the largest moon is our moon. However, if Pluto is considered a planet, Charon will be the largest moon in comparison to the parent planet. [66]

After Jupiter's moon Io, the second densest moon in the solar system is our moon. [67] Do you know where the coldest place recorded so far in the solar system is? On the moon, and the temperature is -248 degrees Celsius. [68] [69] [70]

The moon was much closer to the Earth at the beginning than it is now. That time the tides were much higher, much stronger. It probably played a big role in the evolution of life on Earth. [71] Also, the moon keeps the Earth's rotation axis stable. Otherwise, the Earth might have fallen like Uranus. Can you imagine how the seasons would have been if such happened? [72]

Our moon is a big part of life on Earth. Let's see some examples.

There is a type of dung beetle in Africa that uses the moonlight to walk in a straight line.

There is a type of plant called Mormon tea. They have no flowers, but they rely on insects for pollination. But how would insects be attracted to this plant without flowers?

In mid-July, when the full moon rises, this plant secretes some fluid in small dots. And in the moonlight, these dots sparkle like diamonds. And it is this sparkling light show that attracts the insects! [73] [74]

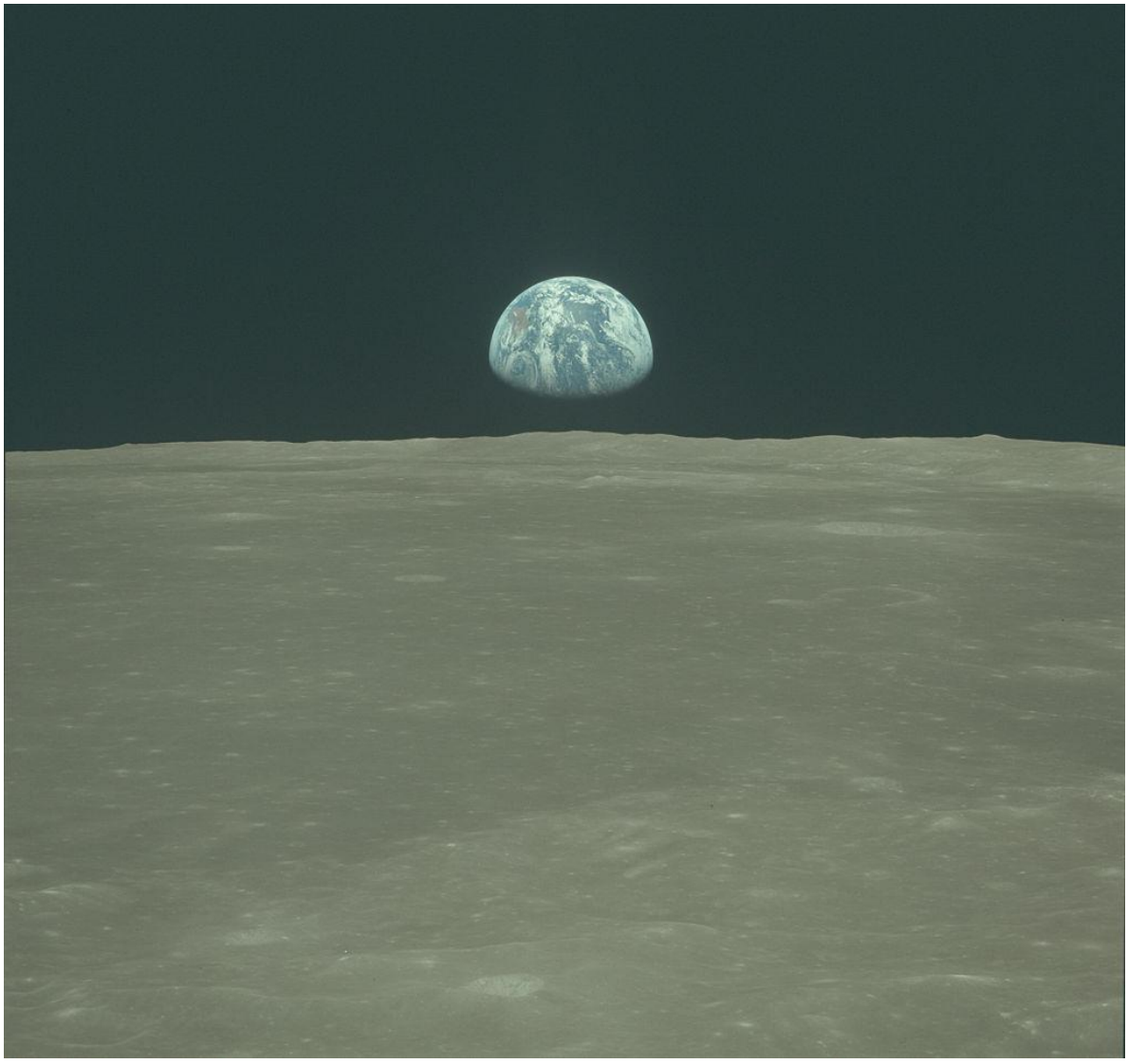


Figure 13: Earth rising on the moon's heaven. This remarkable image was captured by Apollo 11 spacecraft

1. What Is Microgravity? | NASA; What Is Microgravity? | NASA (archive.org);
2. Britannica, The Editors of Encyclopaedia. "freefall". Encyclopedia Britannica, 8 Jul. 2022, https://www.britannica.com/science/freefall-physics. Accessed 3 September 2023.
3. The Science of Interstellar - Kip Thorne - Google Books; chapter 4: Warped Time and Space, and Tidal Gravity;
4. R Penrose (1999). *The Emperor's New Mind: Concerning Computers, Minds, and the Laws of Physics*. Oxford University Press. p. 264. ISBN 978-0-19-286198-6. tidal force.
5. Spacetime Physics, 2nd edition, FREE Download! (eftaylor.com); chapter 2: FLOATING FREE; Edwin F. Taylor, John Archibald Wheeler;
6. newtonian mechanics - Correct explanation of tides - Physics Stack Exchange
7. newtonian mechanics - Moon's pull causes tides on far side of Earth: why? - Physics Stack Exchange
8. Burke, James D.. "Moon". Encyclopedia Britannica, 2 Sep. 2023, https://www.britannica.com/place/Moon. Accessed 3 September 2023.
9. Taylor, G. Jeffrey (31 December 1998). "Origin of the Earth and Moon". *Planetary Science Research Discoveries*. Hawai'i Institute of Geophysics and Planetology. Archived from the original on 10 June 2010. Retrieved 7 April 2010.
10. Tidal Locking | Earth & Tides – Moon: NASA Science; Tidal Locking | Earth & Tides – Moon: NASA Science (archive.org);
11. First Photo of the Lunar Farside - Moon: NASA Science; First Photo of the Lunar Farside - Moon: NASA Science (archive.org);
12. Tidal Friction (gsu.edu); Tidal Friction (archive.org);
13. Microsoft Word - 390lec8 (sfu.ca); Wayback Machine (archive.org); PHYS 390 Lecture 8 - Tidal forces; Simon Fraser University;
14. Dickinson, Terence (1993). *From the Big Bang to Planet X*. Camden East, Ontario: Camden House. pp. 79–81. ISBN 0-921820-71-2.
15. Owen, Tobias Chant. "Charon". Encyclopedia Britannica, 6 Jun. 2023, https://www.britannica.com/place/Charon-astronomy. Accessed 16 September 2023.
16. Szakáts, R.; Kiss, Cs.; Ortiz, J. L.; Morales, N.; Pál, A.; Müller, T. G.; et al. (2023). "Tidally locked rotation of the dwarf planet (136199) Eris discovered from long-term ground based and space photometry". *Astronomy & Astrophysics*. **L3**: 669. arXiv:2211.07987. doi:10.1051/0004-6361/202245234. S2CID 253522934.
17. Galilean Satellites (uoregon.edu); Galilean Satellites (archive.org);
18. Correia, Alexandre C. M. (October 2009), "Secular Evolution of a Satellite by Tidal Effect: Application to Triton", *The Astrophysical Journal Letters*, **704** (1): L1–L4, arXiv:0909.4210, Bibcode:2009ApJ...704L...1C, doi:10.1088/0004-637X/704/1/L1, S2CID 15378780.
19. [1908.05720] Excitation of Tumbling in Phobos and Deimos (arxiv.org); Alice C. Quillen, Mckenzie Lane, Miki Nakajima, Esteban Wright; https://doi.org/10.48550/arXiv.1908.05720; Excitation of tumbling in Phobos and Deimos - NASA/ADS (harvard.edu);
20. Britannica, The Editors of Encyclopaedia. "mare". Encyclopedia Britannica, 9 Jan. 2022, https://www.britannica.com/science/mare-lunar-feature. Accessed 16 September 2023.
21. "Apollo 11 Landing Site". Smithsonian National Air and Space Museum. Archived from the original on December 23, 2017. Retrieved October 12, 2017.
22. Mare (Moon) | SpringerLink; **Encyclopedia of Planetary Landforms** pp 1303–1314; Henrik Hargitai, Ákos Kereszturi;

23. What is the 'Man in the Moon'? | Royal Museums Greenwich (rmg.co.uk); What is the 'Man in the Moon'? | Royal Museums Greenwich (archive.org);
24. Latham, Gary; Ewing, Maurice; Dorman, James; Lammlein, David; Press, Frank; Toksőz, Naft; Sutton, George; Duennebier, Fred; Nakamura, Yosio (1972). "Moonquakes and lunar tectonism". *The Moon*. **4** (3–4): 373–382. Bibcode:1972Moon....4..373L. doi:10.1007/BF00562004. S2CID 120692155.
25. NASA - Moonquakes; Wayback Machine (archive.org);
26. Planetary Satellite Physical Parameters (nasa.gov); Planetary Satellite Physical Parameters (archive.org);
27. Planetary Physical Parameters (nasa.gov); Planetary Physical Parameters (archive.org);
28. Parks, Jake (8 November 2021). "Snapshot: ALMA spots moon-forming disk around distant exoplanet - This stellar shot serves as the first unambiguous detection of a circumplanetary disk capable of brewing its own moon". *Astronomy*. Retrieved 9 November 2021. Snapshot: ALMA spots moon-forming disk around distant exoplanet (archive.org);
29. ALMA Makes First-Ever Detection of Gas in a Circumplanetary Disk - National Radio Astronomy Observatory (nrao.edu) ALMA Makes First-Ever Detection of Gas in a Circumplanetary Disk - National Radio Astronomy Observatory (archive.org);
30. Agnor, C. B.; Hamilton, D. P. (2006). "Neptune's capture of its moon Triton in a binary–planet gravitational encounter" (PDF). *Nature*. **441** (7090): 192–4. Bibcode:2006Natur.441..192A. doi:10.1038/nature04792. PMID 16688170. S2CID 4420518. Archived from the original (PDF) on October 14, 2016. Retrieved August 28, 2015.
31. [1505.07820] NEOWISE: Observations of the Irregular Satellites of Jupiter and Saturn (arxiv.org); Tommy Grav, James M. Bauer, Amy K. Mainzer, Joe R. Masiero, Carrie R. Nugent, Roc M. Cutri, Sarah Sonnet, Emily Kramer; https://doi.org/10.48550/arXiv.1505.07820k; NEOWISE: Observations of the Irregular Satellites of Jupiter and Saturn - NASA/ADS (harvard.edu);
32. [1407.2619] Formation of irregular and runaway moons/exomoons through moon-moon scattering (arxiv.org); Hagai B. Perets, Matthew J. Payne; https://doi.org/10.48550/arXiv.1407.2619; Formation of irregular and runaway moons/exomoons through moon-moon scattering - NASA/ADS (harvard.edu);
33. Stern, SA; Weaver, HA; Steffl, AJ; Mutchler, MJ; et al. (2006). "A giant impact origin for Pluto's small natural satellites and satellite multiplicity in the Kuiper belt". *Nature*. **439** (7079): 946–49. Bibcode:2006Natur.439..946S. doi:10.1038/nature04548. PMID 16495992. S2CID 4400037.
34. Colliding planets | Physics Today | AIP Publishing; Dietrick E. Thomsen; Physics Today 19 (12), 63 (1966); https://doi.org/10.1063/1.3047860
35. Chyba, C. F.; Jankowski, D. G.; Nicholson, P. D. (July 1989). "Tidal evolution in the Neptune-Triton system". *Astronomy and Astrophysics*. **219** (1–2): L23–L26. Bibcode:1989A&A...219L..23C.
36. In Depth | Neptune Moons – NASA Solar System Exploration; In Depth | Neptune Moons – NASA Solar System Exploration (archive.org);
37. The Galilean Moons of Jupiter (colorado.edu); The Galilean Moons of Jupiter (archive.org);
38. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-711470-56-6; pp 382;
39. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-711470-56-6; pp 385-386;
40. Ganymede: A Moon Like No Other | NASA; Ganymede: A Moon Like No Other | NASA (archive.org);

41. Ganymede: The Largest Moon | Science Mission Directorate (nasa.gov); Ganymede: The Largest Moon | Science Mission Directorate (archive.org);
42. Ganymede's Orbital and Thermal Evolution and Its Effect on Magnetic Field Generation - NASA/ADS (harvard.edu); Bland, M. T. ; Showman, A. P. ; Tobie, G.; 38th Lunar and Planetary Science Conference, (Lunar and Planetary Science XXXVIII), held March 12-16, 2007 in League City, Texas. LPI Contribution No. 1338, p.2020;
43. Britannica, The Editors of Encyclopaedia. "Ganymede". Encyclopedia Britannica, 14 Aug. 2023, https://www.britannica.com/place/Ganymede-satellite-of-Jupiter. Accessed 17 September 2023.
44. Britannica, The Editors of Encyclopaedia. "Callisto". Encyclopedia Britannica, 19 Jul. 2023, https://www.britannica.com/place/Callisto-satellite-of-Jupiter. Accessed 17 September 2023.
45. "Callisto – Overview – Planets – NASA Solar System Exploration". *NASA Solar System Exploration*. Archived from the original on 28 March 2014.
46. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-711470-56-6; pp 384;
47. Britannica, The Editors of Encyclopaedia. "Europa". Encyclopedia Britannica, 8 Sep. 2023, https://www.britannica.com/place/Europa-satellite-of-Jupiter. Accessed 17 September 2023.
48. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-711470-56-6; pp 386-388;
49. Britannica, The Editors of Encyclopaedia. "Io". Encyclopedia Britannica, 14 Aug. 2023, https://www.britannica.com/place/Io-satellite-of-Jupiter. Accessed 17 September 2023.
50. ALMA Shows Volcanic Impact on Io's Atmosphere - National Radio Astronomy Observatory (nrao.edu); ALMA shows volcanic impact on the atmosphere of Jupiter's moon Io | NSF - National Science Foundation; ALMA Shows Volcanic Impact on Io's Atmosphere - National Radio Astronomy Observatory (archive.org);
51. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-711470-56-6; pp 388-392;
52. Schenk, P. (2001). "The Mountains of Io: Global and Geological Perspectives from Voyager and Galileo". *Journal of Geophysical Research*. **106** (E12): 33201–33222. Bibcode:2001JGR...10633201S. doi:10.1029/2000JE001408.
53. Global image of Io (true color) (nasa.gov); Global image of Io (true color) (archive.org);
54. Hubbard, William B. and Buratti, Bonnie. "Titan". Encyclopedia Britannica, 19 Jul. 2023, https://www.britannica.com/place/Titan-astronomy. Accessed 17 September 2023.
55. In Depth | Titan – NASA Solar System Exploration; In Depth | Titan – NASA Solar System Exploration (archive.org);
56. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-711470-56-6; pp 392-395;
57. The Outer Planets: Rings (colorado.edu); The Outer Planets: Rings (archive.org);
58. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-711470-56-6; pp 404-405;
59. Hedman, M. M.; et al. (2012). "The three-dimensional structure of Saturn's E Ring". *Icarus*. **217** (1): 322–338. arXiv:1111.2568. Bibcode:2012Icar..217..322H. doi:10.1016/j.icarus.2011.11.006. S2CID 1432112.
60. Lovett, Richard A. (September 4, 2012). "Secret life of Saturn's moon: Enceladus". *Cosmos Magazine*. Archived from the original on August 15, 2014. Retrieved August 29, 2013.
61. "Icy Tendrils Reaching into Saturn Ring Traced to Their Source". *NASA News*. April 14, 2015. Archived from the original on April 16, 2015. Retrieved April 15, 2015.
62. "Ghostly Fingers of Enceladus". *NASA/JPL/Space Science Institute*. September 19, 2006. Archived from the original on April 27, 2014. Retrieved April 26, 2014.

63. Free Astronomy Book for Download - OpenStax; ISBN-13: 978-1-711470-56-6; pp 406-409;
64. Buratti, Bonnie and Hubbard, William B.. "Enceladus". Encyclopedia Britannica, 25 Jul. 2023, https://www.britannica.com/place/Enceladus. Accessed 17 September 2023.
65. Saturn's Rings | NASA Solar System Exploration; Saturn's Rings | NASA Solar System Exploration (archive.org);
66. Planetary Fact Sheet (nasa.gov); Planetary Fact Sheet | Ghostarchive;
67. "Space Topics: Pluto and Charon". The Planetary Society. Archived from the original on 18 February 2012. Retrieved 6 April 2010.
68. Moon/Mercury (uoregon.edu); Moon/Mercury (archive.org);
69. NASA - Ten Cool Things Seen in the First Year of LRO; Wayback Machine (archive.org);
70. Lunar Orbiter Laser Altimeter (nasa.gov); Lunar Orbiter Laser Altimeter (archive.org);
71. Without the Moon, Would There Be Life on Earth? - Scientific American; Without the Moon, Would There Be Life on Earth? - Scientific American (archive.org);
72. Li, Gongjie; Batygin, Konstantin (20 July 2014). "On the Spin-axis Dynamics of a Moonless Earth". *Astrophysical Journal*. **790** (1): 69–76. arXiv:1404.7505. Bibcode:2014ApJ...790...69L. doi:10.1088/0004-637X/790/1/69. S2CID 119295403.
73. How does the Moon affect life on Earth? | Natural History Museum (nhm.ac.uk); How does the Moon affect life on Earth? | Natural History Museum (archive.org);
74. Shrub Attracts Pollinators By Glittering Under the Full Moon (nationalgeographic.com); Shrub Attracts Pollinators By Glittering Under the Full Moon (archive.org);

One and Only Earth-System

In biology, there are different definitions of species. Roughly speaking, those organisms that only reproduce among themselves and are capable of producing fertile offspring are called a species. [1] We draw, horses, donkeys and mules for example. If two horses or two donkeys of appropriate mating types mate, a horse and a donkey will be born, respectively. The same horse and the same donkey will again mate with another horse or another donkey, respectively, and again a baby horse and a baby donkey will be born.

Figure 1: A Liger, hybrid of a male lion and a female tiger.

Now let's ponder about the case of a mule. When a male donkey and a female horse mate and a mule is born. But, if a mule mates with another mule, no offspring will be born. So, even though horses and donkeys are called species, mules are not called a species. Rather, they are known as a hybrid of a horse and a donkey. [2] [3] [4]

The definition and examples of species given above do not fit in all cases. Two new bacteria are born when a bacterium divides into two. In this case, the definition above is not logical at all. There are many more examples like this. However, for our discussion, we do not need to delve that deep. [5]

Mauritius, a small island nation in the Indian Ocean, located near Madagascar in Africa. And the name of an island of Mauritius is Rodrigues. Mauritius and Rodrigues are called "Islands of the Living Dead".

There is valid reason to wonder whether corpses come alive in Mauritius? Why else would they be called such?

The main goal of all living things on earth is to expand their lineage. And looking at it from that point of view, if a living thing cannot expand its lineage, then its survival and death are the same. There are some species of plants on Mauritius and Rodrigues islands that are found only in Mauritius and Rodrigues, and they are no longer able to expand their lineage naturally. So they are called Living Deads and Mauritius and Rodrigues are called Islands of the Living Dead.

The name of such a tree on Rodrigues Island is Café Marron. Scientific name, *Ramosmania rodriguesii*. The incident took place in the 1980s. After a lot of searching for the plant, it was

Figure 2: Café Marron with flower.

thought that the plant had become extinct. And there was only one picture of the plant, drawn in 1877. So, in the mid-1980s, one day a school teacher showed his students the picture of that plant drawn in 1877 and a twelve-year-old student, Raymond Ah-Kee, recognized the plant. The student managed to find the single living Café Marron tree.

But that tree was not producing seeds. Then, to save the tree, some branches of the tree were cut and taken to the Royal Botanic Gardens, Kew in England. From those branches, the researchers there were able to grow a Café Marron tree. And from the branches of that tree, some more trees were born.

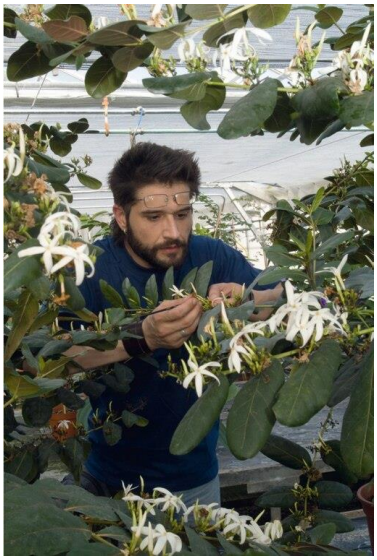


Figure 3: Carlos Magdalena working on Cafe Marron

Although the trees were blooming, there were no sign of fruits, i.e., seeds. That is, the tree has become a living dead. The tree can reproduce only with the help of humans by cutting, not by itself.

Anyway, after a lot of research, the researchers were able to produce a fruit for the first time in 2003. But unfortunately, they did not manage to produce saplings from that fruit. But the scientists did not give up. And at one point they were able to produce saplings. Now in Kew, this irregular cafe maroon produces fruits and saplings are also produced from there. And in this way, a species was saved from the face of death. Research shows that the lack of the conditions required for the seed production of cafe maroon stopped the seed production. However, the matter is much more complex. The growth of cafe maroon, its flower type, etc. also acted as obstacles to seed production.

Figure 4: A sapling of Cafe Marron

However, after producing new seedlings from the seeds, it was seen that the shape, color, of the leaves and stem of all

these seedlings are quite different from the big mother tree. The leaves are long in shape, there is no trace of green. But why such differences? It is assumed that in order to prevent the turtles and birds from assuming the tree as food, the cafe maroon takes on such a form in its infancy. By the way, many of the trees of Mauritius are like this. They bear one appearance in their infancy which different from their appearance when they are grown up. [6] [7] [8]

Figure 5: One segment of Royal Botanic Gardens, Kew.

Just think about it, what would have happened if the twelve-year-old boy had not found the only living cafe maroon tree? Could we ever know about this extraordinary plant species?

Figure 6: World's largest lily, Victoria boliviana

Now we shall discuss another incident. This also took place at the Royal Botanic Gardens, Kew. The fame of the world's largest undivided leaf of a plant goes to a water lily. The leaf is up to three meters in width! Scientific name, *Victoria boliviana*. It was discovered in 2022. Unbelievable, isn't it? How can the plant with the world's largest undivided leaf be discovered in 2022? The story has a bit of a thrilling feel. The world's largest botanical garden is Kew Gardens. And it is here where the worlds largest water lily species was discovered.

Let's delve into a shallow bit of history of Kew Gardens, it won't take more than one line. In 1759, Princess Augusta, the mother of King George III, established a botanical garden and it later became the largest botanical garden in the world. Anyway, in 1837, a water lily plant was brought to this botanical garden. Its name was *Victoria amazonica*. For almost 200 years, it grew bigger in Kew. But in the end, it turned out that it was not *Victoria amazonica* at all, but *Victoria boliviana*, a new species of plant. Although it is always good news to us humans to discover a new species, I think it was like a nightmare for *Victoria amazonica*. Because, before the discovery of boliviana, the fame of being the largest water lily species in the world belonged to amazonica. [9] [10] [11]

Figure 7: Larvae of Pergesa acteus

Let's be somewhat selfish and stop pondering the mental condition of amazonica and wonder this: if a plant species can hide in a place like Kew for 200 years, then how many hundreds of species are hidden from our sight around us?

Have you seen the picture? Isn't it beautiful? Its name is *Pergesa acteus*. It is a larva. How such a larva transforms into a flying moth is surely a wonder. But these larvae surprise me more than the transformed moth. What an amazing effort to survive. How beautifully drawn with shapes and colours their body is! Two long black eyes in front of the head. And there is a small tail like structure too. Yes, that's what I thought when I saw it alive for the first time. It looked like it was patting its eyelids, like one of them… ah let's just skip that one. But I got struck with a bolt from the blue when I found out later, it was neither a head nor two eyes.

Figure 8: An adult male specimen of Pergesa acteus

Actually, what looks as eye to you are called ocelli or eyespots. All the circular spots you see are ocelli, not just the big two. But the big two are unique. Because, these larvae can cover them pulling their skin. Then it seems like they have blinked. Ocelli are basically eye-like spots. But, they are not related to vision. Different animals have ocelli for different purposes. In their case, the purpose is to deceive the predator. When a predator comes to eat them, they see their ocelli and think that they are staring at the predator and the predator gets scared, or something like that. What a defense system for a creature!

Figure 9: The head is not tucked inside in this picture.

And the round part that looks like a head is not actually a head. The head is tucked inside. [12] [13]

No one knows how many more amazing creatures like this there exist. Let's think it this way, all these creatures are inhabitants of a rocky planet called

Earth, that orbits a medium-sized star called the Sun in a medium-sized galaxy called the Milky Way. I have tried to show in the previous chapters how unique the Earth is. How many interesting incidents have occurred on this planet. All the knowledge we have gained so far, all the struggles we have done for it, all of them we did inhabiting this planet. Maybe we have set foot on the moon a few times. But the moon is also a part of the Earth, isn't it? I think, what makes the Earth most unique is its biodiversity. Think about it, humans are also a part of this biodiversity.

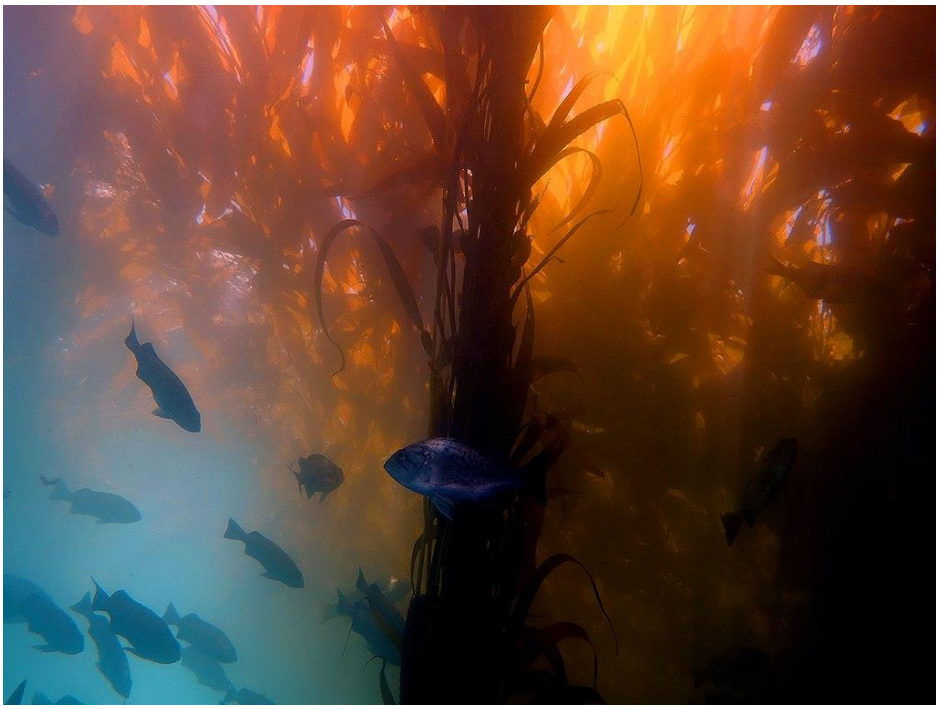


Figure 10: Fishes taking shelter is a kelp forest

But sadly, it is true that we humans are slowly destroying this planet. We are cutting down trees, polluting the environment, destroying biodiversity. We are pushing the only place in the universe where there are such beautiful creatures to destruction. Maybe we are thinking of settling on Mars, but not before smothering the Earth.

I remember a quote from John Wheeler. He said, "We live on an island surrounded by a sea of ignorance. As our island of knowledge grows, so does the shore of our ignorance." [14]

Perhaps he meant that as our knowledge grows, our ignorance will also grow with it. The thing is like this: when you were little, you didn't hear the word elephant. When you first heard it, you wondered, what is an elephant? Your mother then said, an elephant is a quadruped animal. You wondered again, what is a quadruped animal? What do they look like?

So what I want to say is a bit more complicated. Let's get back to our story. You have grown up now. You know what quadrupeds are. How they look. How they reproduce. What they eat, etc., etc., etc. But in the midst of your knowledge, you have forgotten the fundamental question and its answer, what is an elephant?

I mean to say that, as our knowledge increases, we become acquainted with new and new ignorance. Then we get busy with those new and new ignorance. We do not pay attention to our old knowledge. Then suddenly we find that we have forgotten the old knowledge. In Sir

Figure11: Kelp outside of water

Wheeler's language, the ones who are ignorant, fearful and incompetent among us bring sandbags from around and stack them on the coast of ignorance, to enlarge the island of knowledge, and so that the island does not erode in the current of the sea of ignorance. Some brave and capable people like Newton-Einstein are sailing in the sea of ignorance, so that they can collect more resources, which will be better than the sandbags. But when we are sandbags and and moving forward, we do not think of the thicket-jungle that is growing behind us on the island. The island is growing from the front, but behind it is also growing a impenetrable jungle, full of poisonous snakes, venturing into that jungle and sailing in the sea of ignorance are equally difficult.

Establishing a colony on Mars is also like that. Establishing a colony on Mars is definitely a daring and extraordinary task. But in doing so, aren't forgetting our earthly world? Forests are growing on Earth, not forests of trees, but forests of plastic, poisonous gas and radiation. We may think that as Noah (peace be upon him) took all the animals on his boat during the Great Flood, we will also take the whole biodiversity of the Earth on a rocket and go and settle on Mars. In that case, where will you find Rodrigues Island for growing cafe maroon? And what about the new species of water lily discovered in 2022? How many more species are there in the tip of out nose that we do not know about? You may be thinking, what's the big deal if one or two species get extinct? Besides, humans had no contribution in the extinction of dinosaurs, had they?

Figure 12: Massive dense kelps, as if an underwater rain forest

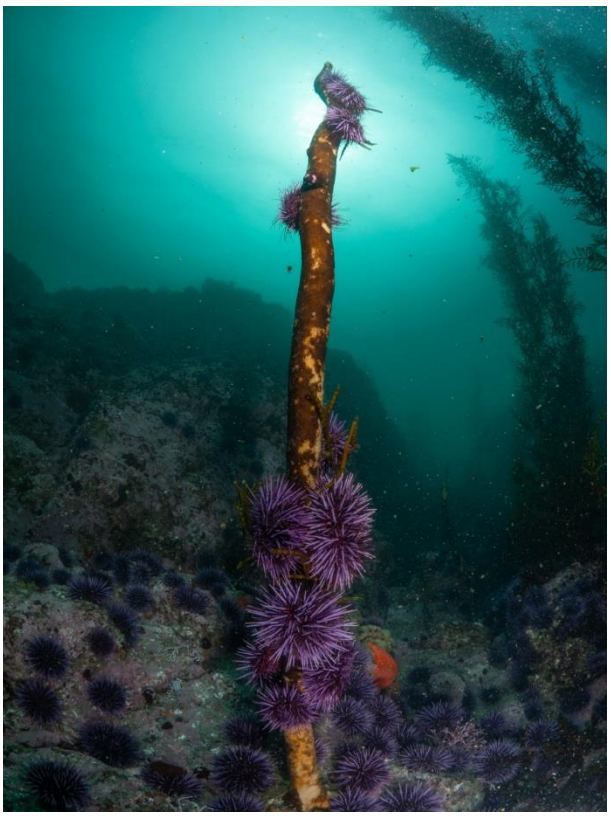


Figure 13: Beautiful violet sea urchins have devoured all the kelps

Actually, the extinction of a species from the earth is a common thing. It happens naturally. But today, for our own selfishness, we have left the earth in such a state that the rate of extinction of various species has increased a lot, which is unnatural. [15] And the biodiversity of the earth depends on each species. So when a species gets extinct, it is seen that many other species fall into trouble for that. There is a type of algae in the sea called kelp. [16] In some places, kelp grows so much that it creates a dense forest-like area under the sea, called a kelp forest. Many marine animals live in the kelp forest because there is both food and shelter. [17] One of the animals found in the kelp forest is the sea otter. They used to be hunted for their valuable leather. At one point, they were almost pushed to extinction by hunting. Anyway, their number decreased and a problem there arrived a problem. One of the main foods of these otters are sea urchins. The number of sea urchins increased at a rapid rate as the number of otters decreased. Again, the main food of these urchins is kelp. The number of urchins increased so much that they eat up almost all of the kelp forests. And as a result, other animals that take shelter in the kelp vanished. As if a desert in the middle of the sea, and the only living creatures are those sea urchins.

But if the kelp forest is gone, what will urchins eat? At one time, they too became extinct from that place. Fortunately, the sea otters did not get extinct wholly. But very few otters were alive. Then, the they were declared protected animals. As a result, their number increased, they stated eating the urchins and the kelp forests too gradually got healthy. [18] [19] [20]

So every species is important. But maybe we can't do anything for the earth even if many of us want to. So for those who want to do something for this Earth-system, this suggestion is for them. Every one of us do browse the internet, don't we? There are the search engines, Google, Bing, Duck Duck Go and how many more. Have you ever heard of Ecosia or Ocean Hero?

These two are also search engines like the previous ones. But do you know the difference? Ecosia spends all the money it earns on tree planting. According to their data, they plant one seedling every 1.3 seconds with the money they earn. Ecosia runs entirely on solar energy. And Ocean Hero spends the money it earns on removing polluting plastics from the sea. According to their data, they can remove one plastic bottle for every five searches. [21] [22]

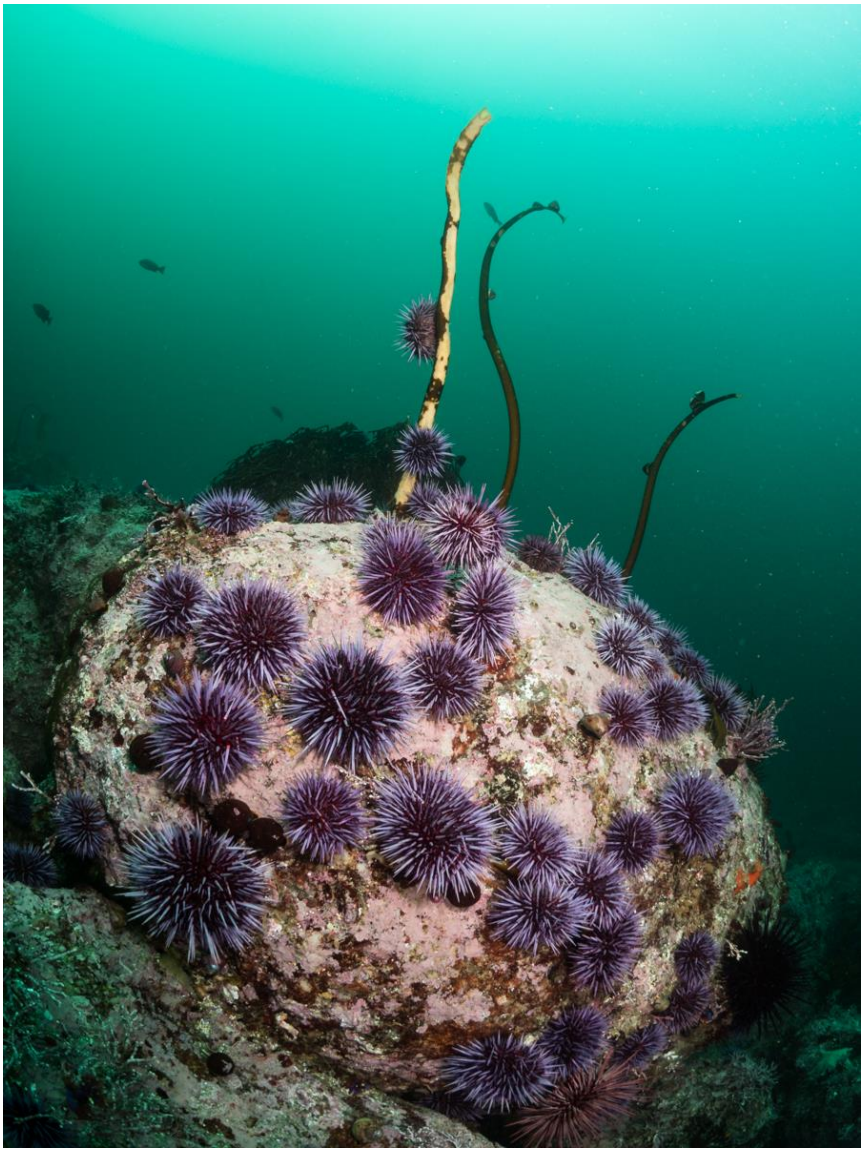


Figure 14: As if the urchins have turned the sea into a vast empty desert

There are so many charity organizations. Through donations, they do many things from tree planting to pollution prevention. But how much can we afford to donate? We want to, but can we? But if we want, we can use Ecosia or Ocean Hero as our search engine and keep the biodiversity of the earth alive for a few more moments. Maybe it's a few milliseconds, or nanoseconds. I'm not saying that Ecosia or Ocean Hero will give you the same experience as those giant search engines, or be as efficient as them. But Ecosia and Ocean Hero are still new. So maybe if you give them time, they can become giants like them someday. And if you don't like any search result from them, you can always go back to those giants once in a while.

And to love biodiversity, you have to know it. You have to know about the animals and plants around you. But how is that possible? How many of the biologists in the country live in the countryside to whom we'll ask if we see a new creature? If you have a camera, you might be able to take a picture of the creature and search the internet, but in my experience, computers are not very successful in this field. So what can be done?

You can try PlantNet. They have both an app and a website. If you upload a picture here, the computer will show you the possible names of the creatures. But don't the search engines do the same thing? Actually, on PlantNet you will find some people who really know the creature you took a picture of. And that's the convenience. [23]

For the very last of the words I want to say, we have to go back to the island that emerged in the middle of the sea of ignorance. It is natural for the jungle to grow on this island. I divide the people of the island into three categories. One category of people who show the courage and ability to sail in the sea of ignorance. They are explorers. The second category of people build dams between the sea and the island. They take the dams forward and increase the span of island of knowledge. Maybe they don't dare to swim even though they have the ability, or maybe they have the courage but not the ability. They are architects, the explorers sail on the sea from the jetty build by these architects. And the third category of people work to prevent the jungle from growing in the middle of the island. They may not have the ability or courage, but they do have to avoid venomous snakes that roam in the jungle. They are curators. If the jungle isn't maintained, it will devour our island of knowledge. Not only will we lose our precious island of knowledge build inch by inch by the architects and explorers, architects on one side of the island will lose the contact with the architects toiling on the other side.

Some of the people belonging to any of these three categories, succeed in their own work, some do not. We see many of the people who should have belonged to one of the three categories, belonging to a category other than that, falling under the pressure of circumstances. Some of them turn out successful, some do not. The problem is, we all want to be explorers and the reason is not unclear. But we forget that the explorers use the knowledge of this island, kept easily accessible by the curators, to explore.

Figure 9: Mother and offspring sea otter, who had the second chance

1. de Queiroz, K. (2005). "Ernst Mayr and the modern concept of species". *PNAS*. **102** (Supplement 1): 6600–6607. Bibcode:2005PNAS..102.6600D. doi:10.1073/pnas.0502030102. PMC 1131873. PMID 15851674.
2. Britannica, The Editors of Encyclopaedia. "hybrid". Encyclopedia Britannica, 15 Nov. 2018, https://www.britannica.com/science/hybrid. Accessed 3 September 2023.
3. (PDF) Why hybrid males are sterile in Drosophila (researchgate.net); Mishra, Paras & Singh, Bashisth. (2005). Why hybrid males are sterile in Drosophila. Curr. Sci. 89.
4. How animal hybrids happen, from ligers to zorses (nationalgeographic.com); How animal hybrids happen, from ligers to zorses (archive.org);
5. Bonner, John Tyler. "reproduction". Encyclopedia Britannica, 22 Aug. 2023, https://www.britannica.com/science/reproduction-biology. Accessed 3 September 2023.
6. Raising the living dead: Ramosmania rodriguesii | Sibbaldia: the International Journal of Botanic Garden Horticulture (rbge.org.uk); Magdalena, C. (2010). Raising the living dead: Ramosmania rodriguesii. Sibbaldia: The International Journal of Botanic Garden Horticulture, (8), 63–73. https://doi.org/10.24823/Sibbaldia.2010.137;
7. 305. RAMOSMANIA RODRIGUESII: Rubiaceae on JSTOR; Bernard Verscourt; Curtis's Botanical Magazine Vol. 13, No. 4 (November 1996), pp. 204-209 (7 pages);
8. The Little Coffee Plant that Wouldn't Die : Krulwich Wonders... : NPR (archive.org); The Little Coffee Plant that Wouldn't Die : Krulwich Wonders... : NPR;
9. "Bolivian waterlily" Archived 2023-01-23 at the Wayback Machine Royal Botanic Gardens Kew. Retrieved 23 January 2023;
10. Brewer, G. (2022, July 4). "Uncovering the giant waterlily: A botanical wonder of the world." Archived 2022-07-04 at the Wayback Machine Royal Botanic Gardens Kew. Retrieved July 4, 2022;
11. History of Kew | Kew; History of Kew | Kew (archive.org);
12. Leong, T. M. & D'Rozario, V. "Larval Development and Metamorphosis of the Hawkmoth, *Pergesa acteus* (Cramer) in Singapore (Lepidoptera: Sphingidae: Macroglossinae)" (PDF). National University of Singapore. Archived from the original (PDF) on 3 October 2016. Retrieved 6 July 2016.
13. Stevens, Martin (November 2005). "The role of eyespots as anti-predator mechanisms, principally demonstrated in the Lepidoptera". *Biological Reviews*. **80** (4): 573–588. doi:10.1017/S1464793105006810. PMID 16221330. S2CID 24868603.
14. Scientific American (1992), Vol. 267, Num. 6, page 20. https://www.scientificamerican.com/index.cfm/_api/render/file/?method=inline&fileID=ED876A80-EB8F-41D2-9FA0156C9FC4D1C2
15. Britannica, The Editors of Encyclopaedia. "mass extinction event". Encyclopedia Britannica, 28 Aug. 2023, https://www.britannica.com/science/mass-extinction-event. Accessed 4 September 2023.
16. Britannica, The Editors of Encyclopaedia. "kelp". Encyclopedia Britannica, 31 Jul. 2023, https://www.britannica.com/science/kelp. Accessed 4 September 2023.
17. What is a kelp forest? (noaa.gov); What is a kelp forest? (archive.org);
18. On Second Chances: The Southern Sea Otter's Return to Ecological Relevance | U.S. Fish & Wildlife Service (fws.gov); On Second Chances: The Southern Sea Otter's Return to Ecological Relevance | U.S. Fish & Wildlife Service (archive.org);

19. Krebs, Charles J. Ecology The Experimental Analysis Of Distribution And Abundance (2014) 40mb : Free Download, Borrow, and Streaming : Internet Archive; page 78;
20. Estes, J. A.; Duggins, D. O.; Rathbun, G. B. (1989). "The ecology of extinctions in kelp forest communities". *Conservation Biology*. **3** (3): 251–264. doi:10.1111/j.1523-1739.1989.tb00085.x.
21. Ecosia - the search engine that plants trees;
22. Our Mission | OceanHero;
23. Pl@ntNet identify (plantnet.org);